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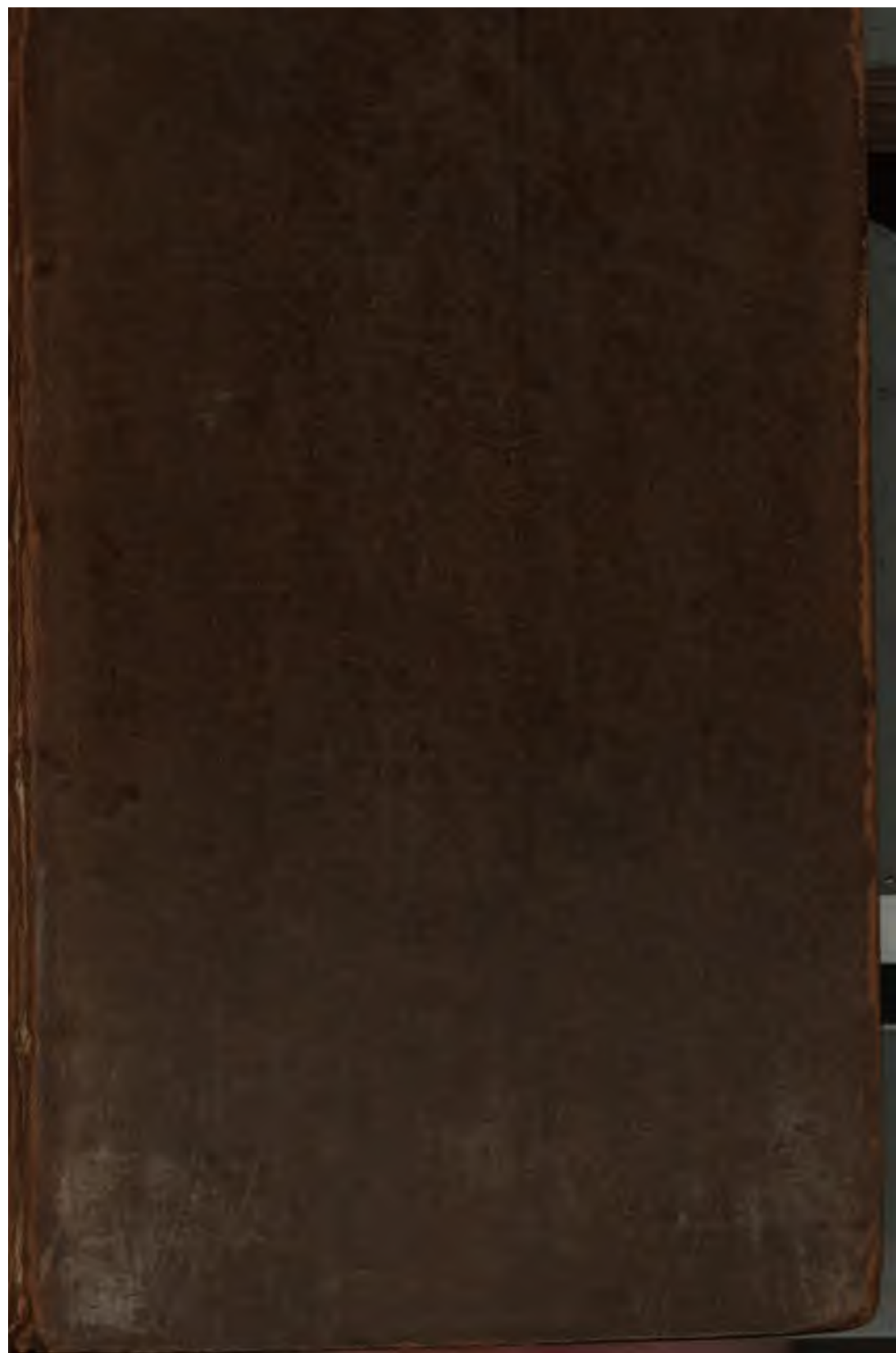
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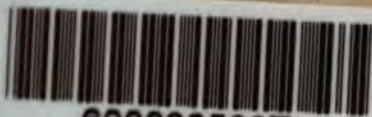
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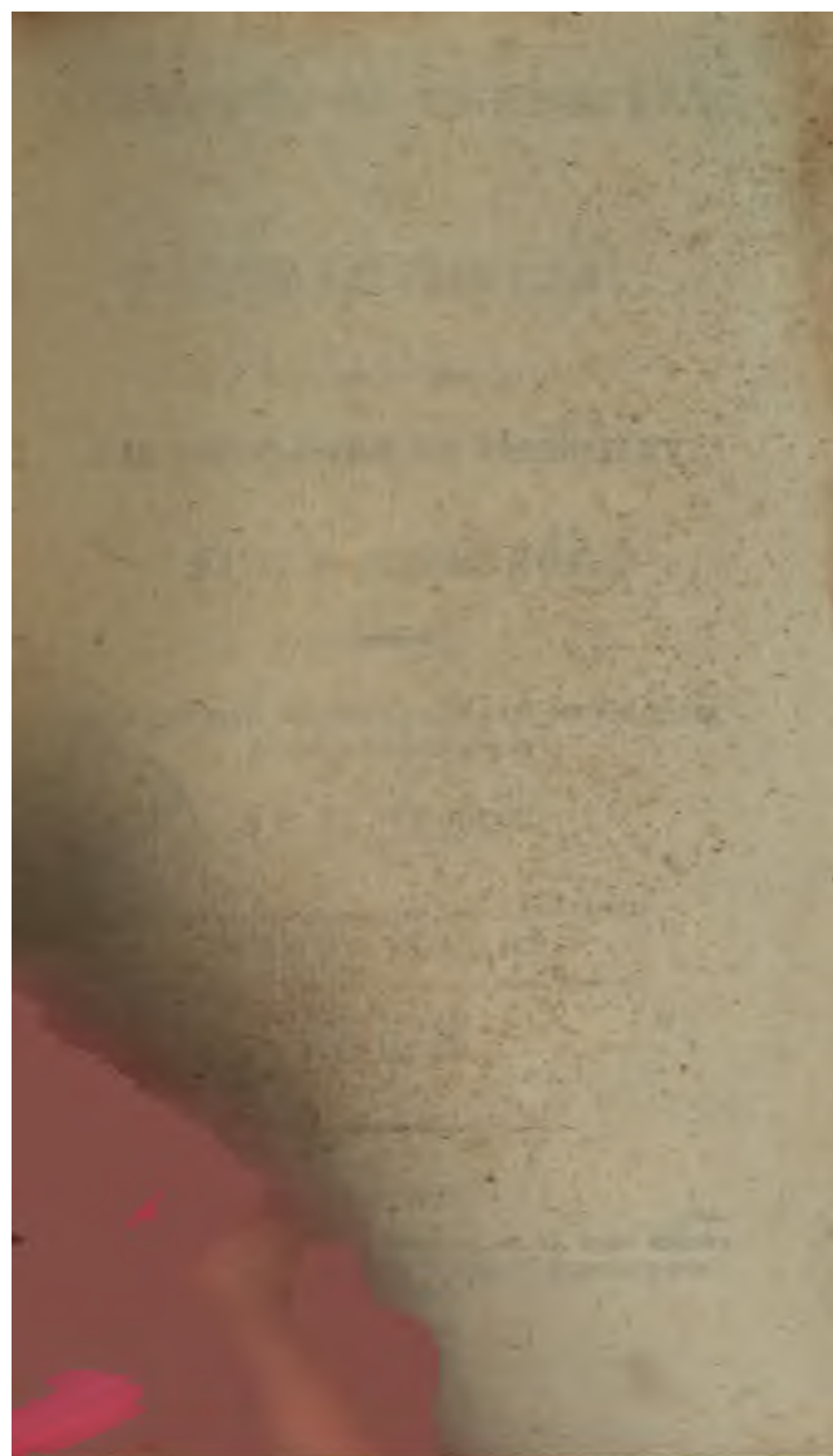
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ELEMENTS OF CHEMISTRY,
AND
NATURAL HISTORY.

TO WHICH IS PREFIXED
THE PHILOSOPHY OF CHEMISTRY.

BY A. F. FOURCROY.

TRANSLATED FROM THE FOURTH AND LAST EDITION OF THE
ORIGINAL FRENCH WORK,



BY R. HERON.

IN FOUR VOLUMES.

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E L E M E N T S
OF
N A T U R A L H I S T O R Y
AND
C H E M I S T R Y.

P A R T I I I.

C H A P X V I I I.

Of Iron.

IRON, to which the alchemists gave the name of *Mars*, is an imperfect metal, of a livid white colour inclining to grey, and disposed in small facets. It is susceptible of a very fine polish, and may be made very brilliant. It is so hard and elastic, as to be capable of destroying the aggregation of any other metal.

Iron emits a smell, especially when it is rubbed or heated. It has likewise a very strong stiptic taste, which acts powerfully on the animal œconomy.

Iron is, next after tin, the lightest of all metallic substances. A cubic foot of forged iron weighs five hundred and eighty pounds. It may be hammered into plates; but being very hard, and liable to become much harder under the hammer, it cannot be beat into leaves. Its ductility, when drawn into wire, is much more considerable: it is drawn into very fine threads, which are used as strings to harpsichord keys. This property appears to depend on its tenacity. Iron is in fact the most tenacious of all metals, next after gold. A thread of iron one tenth of an inch in diameter is sufficient to support, without breaking, the weight of four hundred and fifty pounds.

Pure iron has a peculiar crystalline form. In furnaces in which iron has been slowly cooled, there are found quadrangular pyramids articulated and branched, and consisting of octohædrons inserted one into another. We owe this observation to M. Grignon, master of the forges at Bayard in Champagne. Lastly, beside all the properties which iron possesses in common with other metallic substances, this metal exhibits three properties which are entirely peculiar to itself. One of these is magnetism, or the property of being liable to be attracted by the loadstone, and of acquiring the virtues of the loadstone, either when it has remained long in an elevated situation; or in a direction between north and south; or when it has been employed as a conductor to the electric fire of thunder, as is evinced by a variety of facts; or when two pieces of iron are smartly rubbed one upon another. The second of the singular properties of iron, is that of taking fire, and melting suddenly when struck with a flint; a phænomenon to which the
poets

poets unanimously ascribe the first discovery of fire. The third property by which it is distinguished, is that of being found with manganese in plants and animals; some of whose juices derive from it their colour: it is even probable that those organic beings themselves form the metal; for plants growing in pure water contain iron, which may be obtained from their ashes.

Iron is a metal which abounds very much in nature; for, independently of what plants and animals contain, it is found in almost all coloured stones, in bitumens, and in most metallic ores. But here we are to treat only of such mineral matters as contain a great deal of iron, and are wrought for the purpose of extracting the metal from them. In these ores, which are very numerous, iron exists either in a metallic state, or in the state of an oxide, or mineralized by different substances.

1. Native iron is distinguished by its colour and malleability. It is very rare, and is only found accidentally in iron ores. Margraf found it in a fibrous form at Eibenstein in Saxony: Dr Pallas has discovered, in Siberia, a mass amounting to 1600 pounds; and M. Adanson asserts, that it is common in Senegal. Some mineralogists think that those specimens of native iron are products of art, and have been on different occasions buried under ground.

2. Ores of black iron, taken in general, seem all to belong to an oxide of black iron, more or less pure.

Black iron is distinguishable by its colour, by its property of being more or less susceptible of attraction by the loadstone, and by being altogether insoluble in acids. This iron is sometimes crystalized in the shape of polyhedrons, or round plates, and presents different

Of Iron,

shades of the most brilliant changing colours ; such is that from the island of Elba. It there forms a considerable mountain, which is wrought above ground. The ore from Sweden is likewise a black iron, but not crystallized ; it consists of masses, more or less solid, mixed with quartz, spar, asbestos, &c. It is frequently so hard, as to admit of a polish, and its surface appears like a mirror. Thus it, as well as the former, has obtained the name of *specular iron* : it is found united in considerable quarries. This iron varies in the degree of its colour : some is perfectly black, which is highly susceptible of attraction by the loadstone ; some bluish, which is less so ; and some grey, which possesses this property in a very small degree. The iron of Norway is likewise a black iron ; but it is generally in small scales, like mica, often mixed with garnets and with shorls. Black iron is sometimes found in grains. It is likewise crystallized in cubes ; which has made some naturalists give it the name of *galena of iron*, or *eisen-glanz*. When micaceous iron ore is of a black colour, it is called *eisen-man* ; especially if the scales be very large. When these scales are red, and covered with dust of the same colour, it gets the name of *eisen-ram*. The species of iron ore in black octohædral crystals very regular and dispersed in a kind of schistus, or hard steatite, which comes from Sweden, Corsica, &c. seems to belong to this class of iron ores. It is attracted by the loadstone, and very brittle. The lamellated brilliant iron of Framont belongs also to this species.

Though the several species of black iron ores, which I have joined together in this article, seem to bear an evident analogy with one another, several mineralogists have regarded them as very different, and have arranged

them separately. This variety of opinions originates from our not yet having sufficient knowledge of their nature. It should seem, that of these ores some approach nearer to the metallic state, as the octohædral iron of Corfica and Sweden, which M. Monge compares to martial ethiops. This species is strongly attracted; others, on the contrary, approach nearer to the state of oxides, as the iron of the island of Elba, and particularly the *eisen-man*, and *eisen-ram*, which are not liable to be attracted by the loadstone. The ores of the island of Elba appear to be only black oxides of iron produced from carbonate of iron reduced by means of fire. In this way M. Vauquelin has imitated them with great success. To this account of black irons, I shall here subjoin some observations made by the Abbe Haüy, of the academy of sciences. He distinguishes two primitive shapes of these irons, which, according to him, announce two ferruginous substances of different natures.

One is a regular octohædron. To this belongs the iron of Corfica. The crystals of this species are strongly attracted by the magnetic bar. The specular iron ore from the golden mountain, in octohædral segments, is a variety of this species.

The other is the shape of a cube. To this last belongs particularly the iron ore of the island of Elba, of which there are two principal varieties, namely, 1. iron in rhomboids, very obtuse; 2. iron with six pentagons, and eighteen triangles. These varieties are but feebly attracted by the magnetic bar. By filing, M. Haüy obtained from them a reddish unctuous powder, similar to that of red micaceous iron, or the *eisen-ram* of the Germans:

3. Iron is very often in the state of rust, more or less oxidated. It then forms ochraceous iron ores. All earths coloured brown or red are of this kind.

4. We must beware of confounding with ochres those iron ores which are called *bog ores*. They do, indeed, contain oxidated iron; but that oxide is combined with carbonic acid, and with phosphoric acid, which appears to have been produced by the decomposition of vegetables. Bog irons are distinguished into rich and poor, fusible and dry. The rich is only iron a little rusted, and contains but a very small proportion of earth. Fusible iron melts very easily, and affords cast iron of a good quality; the metal being in it united only to some stones which easily melt. Dry iron is more calcined, and mixed with some very refractory substances. All bog iron, in general, is usually arranged in layers, like stones, and appears evidently to have been deposited by water. It is often in the form of pebbles, or flat irregular spherical bodies. Organic matters, such as wood, leaves, barks, shells, are not unfrequently met with in the state of bog iron. This kind of transmutation seems to suggest the idea, that there is some analogy between iron and organic bodies. A portion of phosphate of iron, contained in these, which abound more than any other iron ores, communicates to this metal the property of being brittle when cold. Bergman, who was acquainted with iron in this state, but did not determine its nature, called this phosphate of iron *siderites*; some German chemists have since called it *water iron*. We will afterwards explain how this salt may be separated from iron that is brittle when cold.

5. The eagle stone, or *atites*, is a variety of bog iron.

Eagle

Eagle Stones are bodies of various forms, commonly oval or polygonous, consisting of concentric layers, disposed around a nucleus, which is often moveable in the centre of the stone. The drying and contraction of these layers has formed a cavity in the middle, in which some fragments of various sizes float at liberty. This stone has received its name from an opinion, that eagles put it into their nests, and that it helps them to lay their eggs more easily, and promotes the effects of incubation. It has been hence inferred, that this stone would act powerfully on the fœtus in the mother's womb. Some authors go so far as to assert, that the pains of a lying-in woman may be brought sooner on by binding an eagle stone to her thigh, and kept back by binding it to her arm. •

6. The *hæmatites* is a kind of bog iron, which appears to be formed in the same manner as *stalaçtites*. It derives its name from its colour, which is commonly red like blood, though subject to varieties. The *hæmatites* usually consists of layers covering one another, and composed of convergent needles. The superficies of this ore is covered over with tubercles. *Hæmatites* are diversified, not only by colour, but by form too. There is, for instance, the needled *hæmatites*, the *hæmatites* in bunches of grapes, or *hæmatites botrytis*, &c. These ores are pretty often found with muddy iron; and are deposited on a great many different bodies.

7. The *loadstone* is nothing else but an ochraceous iron ore, very hard and very refractory; which, however, some persons think not very remote from the metallic state. It is known by its property of attracting filings of steel. It is found in Auvergne, and in Biscay in Spain. It is distinguished by the diversities of its colour into several varieties:

8. *Emery, Smyris*, is a grey or reddish iron ore, considered by a number of mineralogists as a kind of hæmatites. It is very hard and refractory : great plenty of it is found in the isles of Jersey and Guernsey. It is ground in mills into a powder, and used in this form for polishing glass and metals.

9. *Sparry iron* is an oxide of iron in combination with carbonic acid, and transported by water. It is usually of a white colour; but there are specimens of this ore stained with almost every different colour, grey, yellow, red: It is always in plates of various sizes, and semi-transparent like spar. It is of considerable gravity, and is often regularly crystallized : it is found in considerable quarries, often mixed with pyrites, as for instance at Alleverd in Dauphiny; sometimes it is mixed with grey silver ore, as the iron of Baigorry; and sometimes with manganese, as that of Styria. Some chemists think it to be a spar in which the metallic oxide has been deposited. Sparry iron is decomposed by itself in close vessels; and it then yields carbonic acid. What remains is a brilliant black iron, subject, in a high degree, to the attraction of the loadstone, and which may be easily melted by the action of a strong fire. The manganese which it frequently contains, renders it liable to be altered by the action of air, and makes it take a brown colour, as it loses its form and consistency.

10. Nature likewise presents us with iron in a saline state, combined with the sulphuric acid, and forming sulphate of iron, or green copperas: This salt is found in the galleries of iron mines, especially in such as contain pyrites. It is sometimes found in green crystals, or in the form of beautiful stalactites: on other occasions,
again

again, it is not so pure, but appears to have suffered some alteration. If it has lost only the water of its crystallization, it is of a white or a greyish colour: it is then called *fori*. When somewhat more thoroughly calcined, it is yellow, and is called *miffy*. If the calcination has been carried so far as to drive off a considerable part of the acid, the sulphate of iron is then red, and bears the name of natural *colcotbar*, or *chalcite*; when mixed with inflammable matters, this salt is called *melanteri*, from its black colour. All these matters have received the common name of *atramentarious* stones, as being, no less than sulphate of iron, proper materials for making ink.

11. Iron is often found in combination with sulphur; it then forms *martial pyrites*. This ore has received the name of pyrites, because it is hard enough to afford a great abundance of sparks when struck with steel. We call this combination native sulphur of iron. Martial pyrites are commonly in small round masses, which are sometimes regular. They are most generally spherical, cubic, or duodecahædral. Their form is subject to many varieties; a fact which the reader of Henckel's Pyritology cannot fail to be convinced of.

The abbe Haüy, who has paid much attention to the structure of ferruginous *pyrites*, has discovered the following principal varieties in their shape.

1. The *smooth cube*: this is the primitive form of this mineral.
2. *Pyrites* in regular octahædrons.
3. *Pyrites* in cubo-octahædrons: this is the cube with truncated angles.
4. *Duodecahedral pyrites* with pentagonal sides.
5. *Cubical pyrites* striated on three sides.

He has shown that the cube, whose striae so much embarrassed Stenou and Mairan, by the diversity of their directions, was nothing but a modification produced by a hasty crystallization of the duodecahedron, with pentagonal sides.

6. *Pyrites* with twenty triangular faces, eight of which are equilateral, and twelve isosceles.

7. *Pyrites* with thirty-six triangular isosceles faces twelve of which are broader and longer than the other twenty-four.

8. *Globular pyrites* set with octahedral points; this seems to be of a different nature from the preceding.

Some pyrites are externally brown and iron coloured; the greater part are yellowish, and even at the surface pretty much like copper ores. They are all yellow, and of a copper appearance within; and they consist mostly of needles, or pyramids of a number of sides, with their summits converging towards a common centre. Pyrites are usually dispersed near beds of iron ore, and scattered among clays, and through coal mines. The uppermost stratum of a coal mine is almost always pyritous. All pyrites are easily decomposed. No strong heat is requisite to drive off the sulphur which they contain. They almost all alter of themselves when exposed to the air, especially if the situation be moist: they swell, break, lose their lustre, and are covered over with a greenish white efflorescence, which is nothing else but sulphate of iron. It appears that this alteration, which has been called the *vitriolization of pyrites*, depends on the joint action of air and water on the sulphur. Sulphuric acid is thus formed; which, dissolving the iron, rises above the pyrites in a form resembling vegetation,

by

by separating gradually the small pyramids of which the mineral consists. But all pyrites do not effloresce with the same facility. The globulous pyrites, the colour of which is very pale, and the contexture not very close, effloresce the readiest. Such as are of a bright copper yellow, and consist of small plates very neatly arranged one over another, effloresce not without great difficulty, and should be carefully distinguished from the former, as they differ from them in colour, form, texture, and other properties.

12. Iron is likewise met with in combination with arsenic, and both of them in a metallic state. This ore, which is true *mispickel*, is white, sparkling, granulated, or with facets, and does not, like the arsenical pyrites, properly so called, contain any sulphur. Wolfram was formerly thought to be arsenical iron ore; but is now known to be tungsten ore.

13. Iron is sometimes found in the form of a blue powder; sometimes of a brighter, and sometimes a deeper colour. In this state it is called *native Prussian blue*. It is mixed with vegetable earths, particularly peat-earth.

14. Lastly, as iron is more plenteous than any other metal, it is often found mixed with sand, clay, or chalk; and a great many earths and stones are coloured by it.

Iron ores are assayed in the dry way in the following manner: After being reduced to powder, they are mixed with twice their own weight of pounded glass, one part of calcined borax, and a little powdered charcoal; this mixture is well triturated: it is then put into a crucible, with a little marine salt added to cover the crucible, and urged with fire till it melt. When the whole becomes perfectly cool, it is found to contain a

small

small spherical button of iron, often crystallized at the surface, and more or less malleable.

Bergman proposes the assaying of iron ores in the humid way. He employed the muriatic acid to dissolve iron, and precipitated it by an alkaline prussiate. When there were other metals mixed with the iron, he calcined and separated them by the nitric and the acetous acids; and after that dissolved the iron by the muriatic acid.

The treatment of iron ores is varied according to the state of the metal. Some ores need no preparation before they be melted; others must be pounded and washed, sometimes even roasted, to render them soft and fusible.

Muddy iron and sparry iron are wrought in the same way; both being melted on coals. The furnaces used in melting iron vary in height from twelve to eighteen feet. Their cavity is in the form of two quadrilateral pyramids, with their bases joined nearly at the middle of the height of the furnace; this cavity is called (in French) *etalage*. A hole, through which the metal may pass when melted, is perforated through the bottom of the furnace; corresponding to this hole, which is stopped with earth, there is a triangular channel cut in the sand, to receive the metal. The operation begins with putting into the bottom of the furnace a few pieces of burning wood; coals are laid upon the wood; and upon the wood the ore, with some matters to promote its fusion. The matters employed for this purpose are usually calcareous stones, called (in French) *castine*, with some argillaceous stones, under the name of *arbue*, and sometimes quartz or flints. The ore, the stones, and the coal, are alternately put into the surface, care being

being taken to cover over the whole mass with a layer of coal, which must reach to an equal height with the upper opening of the furnace. Thus disposed, the mass is urged with two large bellows till it melt. When the iron melts, it passes through the coals, and is thus reduced to a metallic state. The stony matters, as they melt and vitrify, contribute to the fusion of the iron, which begins at the narrowest part of the furnace. The melted metal is collected at the bottom of the furnace into a place called the *crucible*; from this it runs through the aperture in the bottom of the furnace into the reservoir prepared for it in the sand. It here forms what is called *cast iron*. A vitreous matter called *slag* passes after the iron: it is formed by the vitrification of the gangue of the ore with the earths which were added to facilitate the fusion of the iron. It is of a green, whitish, blue, or yellow colour, which is communicated to it by a part of the oxide of the melted iron.

The iron thus obtained is brittle, and without ductility. Metallurgists differ in opinion concerning the cause of this property of cast iron: some have supposed it to depend on the metal being intermixed with slag. Others have attributed it to the metal not being entirely reduced, but still containing a portion of oxide. Brandt thought it to be arsenic; and M. Sage thinks it is zinc which renders cast iron brittle. Bucquet considered cast iron as iron imperfectly reduced, and still containing an intermixture of oxide. Bergman, after examining this iron with great industry, concluded its fragility to depend on the intermixture of a certain quantity of an extraneous matter, which he thought to be a peculiar metal, and distinguished by the name of *fyderites*:

that matter has been discovered to be a compound of iron with the phosphoric acid. Syderites, as we shall hereafter show, is likewise found in certain irons. The true cause of the fragility, fusibility, granulated texture, and other peculiar properties of cast iron, has been determined beyond a doubt by the ingenious researches of Messrs. Vandermonde, Monge, and Berthollet. They have shown, that cast iron contains both oxigene and coal: the last of which it has absorbed when in fusion in the high furnace. To the various proportions in which it contains these two extraneous bodies, cast iron owes its peculiar properties, and the varieties by which these are diversified.

Metallurgists distinguish various kinds of cast iron; white, grey, black, &c. They give the name of *speckled iron* to that which is variegated with blackish spots on a grey ground. White cast iron is the worst kind; it is almost a semi-metal. The grey is between the first mentioned and the black; which last is esteemed the best, as it affords, the most easily, iron of a good quality. These differences depends on the various proportions in which the oxigene, and still more the coal, is intermixed with the iron. When the proportion of the charcoal is considerable, and it is uniformly intermixed, the cast iron is then black; when the proportion of the charcoal is less, the cast iron is grey. An imperfect mixture, too hastily cooled, gives speckled cast iron. White cast iron contains the smallest proportion possible of charcoal. The nature and the use of cast iron, and the process for converting it into iron, are affected by all of these qualities. The above-mentioned philosophers have discovered, that when cast iron is melted again,
there

there is always separated from it a portion of charcoal intimately combined with iron. This compound, which has been hitherto called *plumbago*, forms a crust on the ladles in which the cast iron is taken out to be cooled.

In order to convert cast iron into iron, it must be purified from the coal and the oxigene which it contains. A strong fire, which may penetrate through the whole mass, is requisite to effect this reduction. At an high temperature, the charcoal naturally attracts the oxigene, burns, and is disengaged with effervescence, in the form of carbonic acid gas. To accomplish this, the cast iron is taken to a refining furnace. It is a forge-furnace, with its hearth somewhat hollow; the cast iron is put into it, and covered over with a good deal of charcoal. The fire is now blown till the cast iron be melted; when brought into this state, it is repeatedly stirred, with the heat still continued. The stirring causes it to expose more surface to the heat; and by this means the charcoal seizes more of the oxigene, in consequence of which it is more completely burnt, and disengaged in carbonic acid gas. The metal appears also to detach from itself at the same time a portion of *syderite*, or phosphate of iron. It is next to be hammered into bars. The hammering, by compressing the particles of the metals, contributes to the separation of the carbure and oxide of iron which it still contains; it consequently effects what could not be effected by the fusion from its being incomplete. The iron is repeatedly beaten and heated till it be brought to the desired form and purity. Forged iron is either soft or brittle. Soft iron is very ductile; and when broken, which cannot be done without bending it, it

appears to consist of threads and fibres ; this has gained it the name of *nervous iron*. But its nervous appearance is accidental ; for even the softest iron, if broken smartly at a single blow, does not appear nervous ; while the worst iron, if broken with due precautions, may be made to put on this appearance. The grain of this metal affords a better criterion of its quality. The other species of forged iron is more brittle : it has coarse grains, and appears to consist of small scales : This, again, is either brittle when hot, or brittle when cold. The cause of its fragility is now known. That which is so brittle when cold is known to contain much more syderite or phosphate of iron than what is contained in any other sort of iron ; still, as iron is more ductile, it is found to contain less syderite ; and the softest iron contains none at all. To separate this salt from iron, and to determine its quantity, the metal may be dissolved in sulphuric acid, diluted in water ; the solution, when suffered to settle, by degrees deposits the phosphate of iron in a white precipitate, which may be taken up and weighed.

Iron is artificially converted into steel. For this purpose, short bars of iron are inclosed in an earthen box, filled with a cement, which is usually made up of very combustible matters ; such as soot from chimnies, or coals of animal matters ; sometimes ashes, calcined bones, marine salt, or ammoniac, are added ; but these matters are often more hurtful than serviceable. The box is now shut, and exposed to heat for ten or twelve hours, till the bars become pretty white, and begin to soften. In this operation the iron is purified, and completely reduced by means of the combustible matters with which it is closely surrounded. Such parts of it

as were not perfectly in a metallic state, are now enabled to return to that state : and the phosphate of iron, if any yet remains, appears to be now entirely decomposed. The iron, being thus softened and dilated, absorbs part of the surrounding charcoal ; and cemented steel appears, therefore, to be a combination of pure iron completely reduced, with charcoal. It differs from iron, as containing charcoal ; and from cast or crude iron, as not containing, like it, any oxigene together with the charcoal. If cast iron be deprived of its oxigene, and yet suffered to retain its charcoal, it will become steel ; and again, if you add charcoal to pure iron, without adding to it any oxigene, it will likewise be converted into steel. Steel is much more fusible than iron ; and therefore bars of iron, converted by cementation into steel, are softened to such a degree, that the carbonic acid, which is disengaged in bubbles, swells the surface of the metal into small cavities, which are sufficiently discernible. The steel which exhibits these appearances is called *ben-steel* *. The differences of steel depend on the iron's having been more or less completely reduced, on the quantity of the charcoal contained in it, and on its being slowly or quickly cooled ; tempering compresses its particles more closely upon each other, and renders it very hard, dry, and brittle.

It is plain, that what renders all these preparations necessary, is, because this metal is more difficult to melt than any other, adheres much more obstinately to the oxygenous principle, and has a stronger tendency to combine with it.

There are ores, especially black iron ores, such as

• *Acier poule.*

that of the isle of Elba, in which the metal is so plentiful, and so little altered, that there is no occasion for converting it first into cast iron. It is only softened in a refining furnace, and immediately submitted to the hammer. This is called the *Catalan method*. It cannot be used, except with ores which contain but a small portion of extraneous matters that can run into *slag*.

Sparry iron ores afford iron so pure, and so easily reducible, that they melt very readily, and greedily absorb charcoal as they are reduced. They are on this account called *ores of steel*.

A very intense heat is requisite to melt iron. Iron filings cast into the midst of a pan with burning coals, or even upon the flame of a taper, instantly kindle, and produce very lively sparks; such too are the sparks which issue from a piece of steel when struck against stones. When these sparks are collected upon white paper, they are found to be melted into a kind of drops or scorix. This metal, when exposed to the focus of Trudaine's burning-glass, suddenly emits flaming and burning sparks. Macquer, who melted both steel and iron in that lens, observed steel to be the most fusible of the two; which is owing to its being combined with charcoal. When melted iron is slowly cooled, it takes, as we have already observed, a peculiar crystalline form. M. Mongez describes it as a pyramid with three or four sides.

A stream of vital air poured on iron in filings, causes it to burn with as much rapidity as the heat of the focus of the lens in the garden *de l'Infante*. If into a bottle filled with vital air you immerse a piece of iron wire, twisted into a spiral line, with a small bit of light-
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ed tinder at one end, the metal suddenly takes fire, and burns with a rapidity and a flame which are very remarkable. As in all these instances of fusion the iron becomes brittle, is reduced to oxide, and at the same time takes a black colour, iron-smiths, and all who have any occasion to work the metal, consider it as not being fusible; and with them it is a maxim that iron is absolutely infusible. This opinion, however, proves, when strictly examined, to be erroneous; for when submitted to the action of a very strong fire, without being at the same time exposed to the action of air, iron melts almost without alteration. In our accurate experiments, we obtain small buttons of soft ductile iron.

Iron, though so very hard and refractory, is very easily calcined or reduced to oxide. As soon as it begins to turn red hot, it combines with oxigene, and burns without any discernible flame. A bar of iron, after being kept red-hot for a considerable time, exhibits on its surface scales which may be beaten off with the hammer, (and are called by the French workmen *battitures de fer*). The metal of these scales is but oxidated in part, for they are still liable to be attracted by the loadstone. A more perfect oxide of iron may be obtained by exposing filings of steel under a muffle; and this will take place still more readily with scales of iron. These are converted into a reddish brown powder, not liable to be attracted by the loadstone, which is called *astringent saffron of Mars*. We call it *red oxide of iron*; and the scales we called *black oxide*. The black oxide contains from 20 to 25 parts of oxigene to the hundred; the red oxide contains from 32 to 34 of the same principle. The oxides of iron differ according as they ap-

proach nearer to the one or the other of these two degrees. Some are of a yellow brown colour; others chestnut; and others, again, of a most beautiful red, like carmine. All of these oxides, when mixed with earthy matters, and exposed to a very strong heat, melt into a blackish porous glass. They are in part reduced when heated slowly in close vessels. However short the time during which they have been exposed to the air, they give out, when reduced, a certain quantity of carbonic acid; a circumstance which proves that they attract this acid from the atmosphere. This acid is also produced from the charcoal which the iron contains, and which becomes acid by absorbing the oxygen disengaged from them as they are reduced.

Red oxide of iron is very easily reduced with the help of combustible matters. On being mixed with a little oil, and heated slightly in a crucible, they become black, and very subject to the attraction of the loadstone: But in this operation they lose not all the oxygen which they contain; they only pass into the state of black oxide.

The purest iron soon loses its metallic lustre when exposed to humid air: it is then covered over with a pulverulent brown yellow crust. This matter is called *rust*. Common iron is much more liable to rust, than steel. The more the particles of the metal are attenuated and divided, the more rapid is the alteration which it suffers from air. On this principle is prepared the medicine known in pharmacy under the name of *aperient saffron of Mars*. To produce it, iron filings are exposed to the air, and watered; and by this means they come to rust very speedily. It is formed still more quickly

quickly of iron in the state of *Æthiops*, or black oxide, treated in the same manner. In this alteration the metal is agglutinated into masses, which are levigated before being employed in medicine. The formation of the rust of iron was thought to be owing to the action of the air; but it is now known to be water which calcines the metal in this manner. Some experiments peculiar to myself lead me to consider *aperient saffron of Mars* as a combination of oxide of iron with carbonic acid. I have distilled *this saffron of Mars* in a pneumatocchemical apparatus, and obtained from it a large proportion of this acid. The iron was then changed into a black powder, very subject to the attraction of the loadstone. M. Joffe, apothecary at Paris, has communicated to the Royal Society of Medicine a similar process for obtaining speedily *martial Æthiops*. He advises the making the *aperient saffron of Mars* red-hot in a retort, with a balloon perforated with a small hole, fitted, but not luted, to it. By this means the heat disengages the carbonic acid, which M. Joffe suffers to escape through the hole perforated in the balloon; and the iron then remains in the state of black oxide in powder, or *martial Æthiops*. I have by this means often crystallized caustic potash, and soda, rubbed over the sides of the balloon fitted to the retort. In consequence of the carbonic acid, from the iron, uniting with one or other of the alkalis, the neutral salts are formed, to which we have given the name of carbonate of potash or of soda. I have made many other experiments, and have given an account of them in a particular Memoir, (*Chem. Mem. & Observ.* 1784). From all of them I am convinced, that this matter is a true neutral salt, formed

by oxide of iron with the carbonic acid. Rust should therefore be called *carbonate of iron*, to distinguish it from the genuine oxides of this metal. This salt is precisely the same with what Bergman calls *aerated iron*. This theory, too, has been adopted by Macquer. It explains very naturally how iron comes to contract rust so speedily in humid and impure air; how it comes to be altered, so quickly, and so entirely, in places where the air is corrupted by the respiration of animals, by combustion, or by vapours proceeding from animal matters; as, for instance, in stables, stalls, and houses of office, &c. Iron is of all metals the most liable to alteration from the contact of air, and the alteration is not confined to its surface. Very thick bars of iron are often rusted half way through.

Water acts powerfully on iron when cold. It divides it, and even dissolves a part of it, according to the experiments of M. Monnet. The purer the iron is, and the more air the water contains, so much the more of it does it dissolve. When iron is for some time stirred about in water, it appears to be divided into very minute parts; and on decanting the water, which is a little turbid, it deposits a very fine black powder, which has received the name of *Lemery's martial Æthiops*. This powder must be carefully dried by a moderate heat, and in a close vessel, such as an alembic, lest the contact of the air should rust it. This martial Æthiops is very subject to the attraction of the loadstone; it is a black oxide of iron formed by water. As this operation is very tedious and delicate, various chemists have attempted to simplify it. Rouelle, in making up this preparation, made use of the *mouffoirs de la Garaye*, and by that means

means obtained a very fine *Æthiops*, in much less time than is consumed in Lemery's process. I believe M. Joffe's method, which is much more expeditious, might be advantageously substituted in its place. We will hereafter give some other processes for preparing *martial Æthiops*. Lemery's is effected by an actual decomposition of water; hydrogenous gas is disengaged, and the iron is oxidated by absorbing twenty-five parts of oxigene to a hundred. We will very soon treat more at length of this decomposition of iron by water.

We have already mentioned, that when steel in bars is heated to a certain degree, and suddenly immersed into cold water, it becomes very hard, and very brittle. The hotter the steel, and the colder the liquor into which it is immersed, so much the more eminent do these qualities become. This operation is called *tempering*. Steel may at pleasure be caused to assume any degree of hardness. We can also deprive it of its *temper*, by heating it to the same temperature at which it was tempered, and suffering it to cool slowly. This effect of water on steel appears to depend on the sudden cooling producing a change in the disposition of its parts, and injuring its crystallization. All metals admit of being hardened by tempering; but the more infusible the metal, so much the more eminent the degree in which it acquires this quality. Iron, therefore, is more susceptible of it than any other.

About two years since, a much stronger action was discovered to take place between water and iron. M. Lavoisier putting iron and water together into bell-glass above mercury, observed that the iron rusted, and the water decreased in quantity in proportion as an elastic

fluid which filled the upper part of the apparatus was disengaged. The fluid disengaged proved to be *inflammable gas*. The iron had gained an additional weight, and was oxidated; M. Lavoisier conjectured, that the water might contain oxigene, and that the inflammable gas, the other principle of the water, might be disengaged, in consequence of the oxigene uniting with the iron. He afterwards made a more decisive experiment, in conjunction with M. Meusnier: in that experiment, water in vapour introduced into a gun-barrel made red-hot, afforded a large proportion of *inflammable gas*: The inner part of the gun was found to have acquired additional bulk, and was become black, brittle, and lamellated, much like the iron ore of the isle of Elba; The metal was found to have gained an increase of weight; and the additional weight which it had acquired, taken together with the weight of the *inflammable gas*, corresponded precisely to that of the water decomposed. The portion of iron oxidated by this means was found separate from that which had not undergone the same alteration. It formed an interior cylinder, thicker than the exterior part; and differing greatly from it in texture, colour, consistency, and form. In order to succeed in this experiment, it is requisite to heat the iron to a white red; for heat contributes greatly to the separation of the principles of the water. And when the gun-barrel is not thoroughly red-hot, and the water not in an highly elastic state when it passes through it, no *inflammable gas* is disengaged, nor is the water decomposed. This has happened with various philosophers; who not making the iron hot enough, and introducing the water into it in a liquid state, have not obtained the same results as

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M. Lavoisier, and have of consequence denied water to be decomposable, though Synthesis concurs to justify M. Lavoisier's inferences from analysis, as has been incontrovertibly shown by the same gentleman and M. Mongez. There are many other occasions on which water is, in a like manner, separated into its constituent principles, and gives rise to many very important phenomena, of which we shall hereafter have occasion to take notice. Such is the experiment by which water was discovered to be a compound consisting of 0,14 of hydrogen, with 0,86 of oxygen.

Iron does not combine in its metallic state with earthy or stony matters ; but oxide of iron facilitates the vitrification of all kinds of stone ; communicating to them a green or brown colour. The colours which oxide of iron communicates to other bodies are various, according as it is more or less completely oxidated. This oxide possesses likewise the property of assuming and communicating more or less consistency to those stones with which it is naturally or artificially mixed, and diluted by means of water.

Neither barytes, magnesia, nor lime, acts observably upon iron.

The pure fixed alkalis and ammoniac, when dissolved in water, act in a sensible manner on this metal. In the course of a few days digestion on it, the liquors become foul, and give a precipitate of a small portion of *Æthiops*, or black oxide of iron : And, as has been observed by the chemists of the Academy of Dijon, a certain quantity of hydrogenous gas is disengaged during the action of these substances ; a circumstance which proves, that the water contributes to it, as the hydrogenous gas can

be given out only in consequence of its decomposition ; to which no doubt the alkalis contribute.

Iron may be dissolved in any of the acids. M. Monnet has observed, that the concentrated sulphuric acid cannot act on this metal, unless it be boiling. On distilling this mixture to dryness, there are found in the retort sublimated flowers of sulphur, and sulphate of iron in a white mass, which may be partly dissolved in water, but which being decomposed by heat, affords no crystals. The sulphuric acid diluted in two parts of water, readily dissolves iron filings cold ; at the same time, when the metal is dissolved, a considerable quantity of hydrogenous gas is disengaged. By putting a lighted taper to the mouth of the matrass, after keeping it stopped for some time with the hand, it may be made to detonize with a considerable noise. This gas burns with a reddish flame, sometimes emitting very small sparks, like those of iron filings. Macquer, Bergman, and Mr Kirwan, think that in this instance of combination the sulphuric acid disengages a great part of the phlogiston of the iron, and that the *inflammable gas* belongs solely to this metal. This opinion appears to have been built on the belief, that *inflammable gas* might be extracted from iron alone, without any intermedium, merely by the action of fire. But it is at present a well established fact, that the hydrogenous gas, disengaged from iron by heat, is always in exact proportion to the water it contains ; and it is no less certain, that water added to sulphuric acid gives out, in consequence of being decomposed, hydrogenous gas. 1. Because the concentrated sulphuric acid affords only sulphureous gas. 2. Because in this state it cannot act upon iron without the aid of

heat, and even then acts upon it very faintly. 3. Because, whenever water is added, the action becomes more rapid, and hydrogenous gas is produced. 4. Lastly, because concentrated sulphuric acid is in part decomposed by iron when there is no water added; whereas, when water is added to the solution, the acid remains without diminution, and only combines with the oxide of iron. The proof of this last fact is, that the same quantity of alkali is required to saturate this acid after it has acted on iron as before. In this operation, therefore, it is the water which oxidates the iron, as was long since conjectured by M. de la Place; and has been fully proved by Messrs Lavoisier and Meusnier.

While the sulphuric acid diluted in water acts upon iron, a portion of the metal is precipitated in a black powder, which was taken by Stahl for sulphur, and has been found by M. Monnet to be *martial Æthiops*. That black oxide appears to be more than sufficient for the saturation of the acid. As soon as one part of the iron is combined with one of the acid, although the acid be not nearly saturated, yet the solution ceases, and it no longer acts upon the metal. M. Monnet, who first made this observation, remarks, that when water is poured into the mixture, the acid begins again to act upon the metal. The cause of this phenomenon is, that the water which was united with the sulphuric acid has been absorbed by the sulphate of iron, which is already formed, while the acid which remains unsaturated cannot act upon the iron, till by the addition of a new quantity of water more of the metal be reduced to oxide. The sulphuric acid dissolves more than half its own weight of iron. This solution, after being filtered and e

affords by cooling a transparent salt, of a beautiful green colour, in rhombic crystals. This is the *martial vitriol*, or *green copperas* of commerce. We call it sulphate of iron.

People do not take the trouble of making up this salt artificially, because nature supplies it in abundance, and it is easily extracted from *martial pyrites*. All that is requisite is, to leave those sulphurs exposed for some time to the air. The moisture of the atmosphere contributes to their decomposition; they become covered with a white efflorescence, which needs to be dissolved in water, and crystallized, before it can afford sulphate of iron. This decomposition of pyrites depends, according to Stahl, on a double affinity. Sulphur is with him a compound of *phlogiston* and *vitriolic acid*. Neither water or iron, when taken each by itself, can decompose sulphur: But when these two substances are made to act upon it together, the iron detaches, and attracts to itself the phlogiston of the sulphur, and the *vitriolic acid* combines with the water to dissolve the metal. Such of the pyrites as are less disposed to effloresce, among which are the brilliant pyrites, effloresce readily after being deprived by roasting of a part of the sulphur which they naturally contain. The *vitriol* is separated from it by washing. The solution of this salt deposits at first a certain quantity of iron in the state of ochre. The liquor is not evaporated and crystallized till after this depositum be precipitated. The modern opinion concerning the efflorescence of pyrites is, that the sulphur, which in them is divided as in its combinations with alkaline substances, combines with a portion of oxygen to form sulphuric acid, which being diluted
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by the water of the atmosphere, enters into union with the iron, not without exciting heat, and dissolves it. What adds a very considerable weight to this opinion is, that the contact of air is necessary to the efflorescence of pyrites, and that moisture, which contributes greatly to their *vitriolization*, acts in this instance in the same manner as in the solution of iron. Such is the origin of the hydrogenous gas, which is disengaged in this operation when performed *in vacuo*.

Sulphate of iron has a green emerald colour, and a very astringent taste. It sometimes reddens syrup of violets; but it does not uniformly produce this effect. From the experiments of Kunckel and M. Monnet, it appears that these crystals contain a quantity of water equal to more than half the weight of the salt. If this salt be suddenly exposed to a pretty strong heat, it becomes liquid, like any of the other salts which are more soluble in heat than in cold: when dried, its colour is a whitish grey. If it be heated at a more intense fire, it gives out so much of its acid in the form of sulphureous gas, and becomes red; in this state it is called *colcothar*. Sulphate of iron, when calcined till it becomes red, attracts the moisture of the atmosphere, in a very sensible manner, by means of the sulphuric acid which it contains. When distilled in a retort, and in a reverberating furnace, this salt affords at first a water which is faintly acid, and is called *deu of vitriol*. The balloon must be changed, when we wish to obtain the concentrated sulphuric acid separately; which, when the heat is very intense, appears black as it passes into the receiver, and exhales a suffocating smell of volatile sulphureous acid. What enables it to display these

phænomena is, according to the pneumatic theory, its having lost a part of its oxigene, which has become fixed in the iron. Towards the end of the operation, the acid distilled assumes a concrete crySTALLINE form, and it is now called *glacial sulphuric acid*. This experiment, which is described by Hellot, did not succeed with M. Baumé; but among chemists in general it is considered as certain and infallible. The glacial sulphuric acid, when distilled in a small retort, gives out sulphureous gas, and becomes white and fluid. It owes its concrete state to the presence of this gas. It combines with water with hissing and heat, and on this occasion, too, gives out sulphureous gas. Such is Northausen's fuming *oil of vitriol*, and the concrete salt obtained from it by a moderate heat, of which I have given an analysis in a Memoir published among the Memoirs of the Academy for the year 1785.

The residue remaining after the distillation of sulphate of iron is red, and resembles colcothar. When washed with water, there is separated from it a white salt, but little known, and called *colcothar salt*, or *fixed salt of vitriol*. What remains is a red insipid earth, which is pure oxide of iron, and is called *mild earth of vitriol*.

Sulphate of iron, when exposed to the air, becomes somewhat yellow, and is gradually covered with rust, by absorbing oxigene from the atmosphere. By this absorption of oxigene, it is gradually more and more calcined, till it become incapable of remaining united with the sulphuric acid. A solution of this salt exhibits the same phenomenon when brought into contact with the atmosphere; and either the one or the other may be used as an eudiometer.

Cold

Cold water dissolves a quantity of the salt equal to half its own weight: hot water dissolves still more of it: but when sufficiently impregnated, it becomes turbid by a quantity of earthy matter of no considerable value. This matter is separated from the solution: and the solution, when cooled, gives out green transparent rhomboidal crystals. The impregnated liquor affords, by evaporation, a new parcel of crystals: and after it is deprived of all that it can afford by crystallization, there remains a blackish brown, or a brown yellow mother water, not susceptible of crystallization. When evaporated by a strong heat, and suffered to cool, this mother water forms a soft mucous mass, which powerfully attracts the moisture of the atmosphere. When this mass is thoroughly dry, it affords a greenish yellow powder. According to M. Nunner, the mother water of sulphate of iron contains iron in the state of a perfect oxide. He made himself certain of this fact, by forming directly, with the help of heat, a solution of genuine oxide of iron in this acid. The solution is brown, and not susceptible of crystallization.

The oxide of iron may be separated from the mother water, not only by aluminous earth, but also by copper and iron filings, to which perfect sulphate of iron is not liable.—A strongly saturated solution of this perfect salt, if exposed to the air, changes, in a certain space of time, into a mother water of the same nature with the two last-mentioned, by attracting oxygen from the atmosphere.

Sulphate of iron is decomposable by lime and alkalis. Lime-water poured into a solution of this salt produces a precipitate in flakes of a deep olive green colour; a portion

portion of the precipitate is again dissolved in the water, and communicates to it a reddish tinge. In the years 1777 and 1778, I presented to the Academy two Memoirs on precipitates of iron obtained by caustic alkalis, or by alkalis not caustic, in which I have accurately described the phænomena which attend these precipitations, and the state of the iron in these different circumstances ; I shall here give the chief facts which they afford in relation to sulphate of iron. Caustic fixed alkali precipitates the sulphuric solution of iron in dark green flakes, which are again dissolved in the alkali, forming a kind of martial tincture of a very beautiful red colour. When a smaller portion of the alkali is put into the solution, the precipitate may be taken up and converted into blackish *Æthiops*, or black oxide of iron, by drying it rapidly and in close vessels. If these two precautions were neglected, the iron would very soon become oxide, on account of its being moist and divided. Potash, saturated with carbonic acid, or carbonate of potash, forms a greenish white precipitate, which does not dissolve again in the alkali. This difference is owing to the carbonic acid, which unites with the iron as fast as it is separated from the alkali by the sulphuric acid. Pure or caustic ammoniac produces a precipitate from a solution of sulphate of iron in water, of a deep blackish green, and which does not dissolve again in the salt. By drying it suddenly, and in close vessels, it may be obtained black, and liable to be attracted by the loadstone. The precipitate formed by concrete ammoniac, or ammoniacal carbonate, is of a greenish grey colour ; a part of it is again dissolved in the salt, and communicates to it a red tinge ; so that the
phænomena

phenomena which ammoniac produces in this solution, are in one respect directly opposite to those of the fixed alkalis : caustic fixed alkali dissolves the precipitated iron very readily ; carbonated potash, not without the greatest difficulty.

Astringent vegetable matters, such as nut-galls, sumac, husks of nuts and pomegranates, quinquina, cypress-nuts, logwood, tea, &c. cause sulphate of iron to yield a black precipitate. This precipitate, which cannot be mistaken for iron, is so much attenuated as to remain suspended in the liquor. On adding to this mixture a little gum-arabic, the iron precipitate is permanently suspended, and the composition forms the black liquor known under the name of ink. We do not yet certainly know what passes on this occasion. Macquer, M. Monnet, and many other chemists, think the precipitate of ink to be combined with some principle of the nut-gall which disengages it from the acid. They appear with some reason to think that principle in an oily state. M. Guanetti, a physician at Turin, has made a number of experiments on iron precipitated by astringents from its solutions. The result of his researches, which he has given in his analysis of the waters of St Vincent, proves that this precipitate is not liable to be attracted by the loadstone ; that it becomes so, however, when heated in a very close vessel ; that it is soluble in acids without effervescence ; and that the solution no longer receives a black tincture from nut-galls : from which facts it may be inferred, that the iron is combined with the astringent principle, and that they exist together somewhat in the state of a neutral salt. In the third Volume of the *Elements of Chemistry*, by the Aca-

demy of Dijon, there is a series of experiments on the astringent vegetable principle, which seem to represent this substance as of a similar nature with acids. According to those chemists, it reddens vegetable blue colours; combines with alkalis; decomposes sulphurs; dissolves, and appears to neutralize metals; decomposes all solutions of metals with peculiar phenomena; ascends in distillation, without losing its power of acting on metals, and displays a vast number of other properties which we have not here room to enlarge upon.

The experiments and inductions of the academicians of Dijon have since been confirmed by the researches of Scheele. That celebrated chemist has discovered, that the simple infusion of nut-galls in water, separates from it a peculiar acid, susceptible of crystallization, which detaches iron from any other acids, and communicates to it a black colour, by bringing it nearer to a metallic state. We call this salt the *acid of galls*, or the *gallic acid*. Its history will occur in the vegetable kingdom.

A phenomenon still more difficult to understand than the action of nut-gall on sulphate of iron, is the decomposition of this salt by an alkali calcined with bullock's blood. By this means we obtain a precipitate of a beautiful blue colour, and insoluble in acids. This precipitate is called *Berlin*, or *Prussian blue*, because it was first discovered in the city of Berlin. Stahl relates, that a chemist, of the name of Diesbach, happening to borrow from Dippel a quantity of fixed alkali to precipitate a solution of cochineal, Dippel gave him alkali on which he had distilled his animal oil. The salt caused Diesbach's solution to yield a blue precipitate. Dippel inquired into the cause, and prepared, by a simple process, the

the Prussian blue, which was made known to the world in the year 1710, in the Miscellanies of the Academy of Berlin; but the mode of preparation was not communicated. Chemists laboured eagerly to discover the process for preparing it, and at length succeeded. In the year 1724, Woodward published, in the Philosophical Transactions, a process for preparing this colouring substance.

To make Prussian blue, mix four ounces of nitre, fixed by tartar, with as much dried bullock's blood. Calcine this mixture in a crucible till it be reduced to a coal, and cease to emit flame. Wash it with as much water as may be requisite to dissolve the whole of the saline matter, which is called *phlogisticated alkali*, or *colouring lixivium*; and let this lixivium be concentrated by evaporation. Next dissolve two ounces of sulphate of iron, and four ounces of aluminous sulphate, in a pint of water. Mix this solution with the alkaline lixivium; a greenish depositum is produced, which must be separated by the filter and muriatic acid poured upon it. The depositum then takes a darker and more beautiful blue colour; and is to be dried by a moderate heat, or in the air.

Many chemists have since attempted both to prepare and to form a theory of Prussian blue. As to its preparation, it is at present known, that many other substances render alkali capable of producing a blue precipitate of iron.

Geoffroy, in the Memoirs of the Academy for the year 1725, says, that he found all burnt coals of animal matters capable of communicating this property to alkalis. M. Baumé asserts, that *phlogisticated alkali may be*

pared with the coals of vegetable substances by a stronger heat. Spielman has made it with bitumens ; Brandt with foot. The manufactories of Prussian blue are very numerous ; and in each of them, it would appear, different methods are employed in the preparations. M. Baunach informs us, that in Germany the hooves, horns, and hides of cattle, are used for this purpose. All animal matters, however, do not appear equally proper for the Prussian lixivium. I have attempted ineffectually to prepare it with the bile in the same manner as with the blood of bullocks. What I obtained was an alkali, which produced in a solution of vitriol a greenish white precipitate ; and the precipitate was entirely dissolved in the muriatic acid.

Chemists differ greatly concerning the theory of Prussian blue. Brown and Geoffroy thought it to be the *phlogistic* part of iron extricated by the lixivium of the blood, and united with the aluminous earth. Abbé Menon thought it to be alkali. Macquer, in a Memoir which has deservedly been considered as a master-piece by every chemist, and is inserted among the Memoirs of the Academy for the year 1752, has refuted the opinions of those chemists. He thinks Prussian blue to be nothing but iron, combined with an excess of the inflammable principle which it receives from the *phlogisticated* alkali, and the alkali from the bullock's blood. He observes, 1. That Prussian blue, when exposed to heat, loses its colour, and becomes simply iron again : 2. That this blue is insoluble even by the strongest acids : 3. That alkalis are capable of dissolving the colouring matter of Prussian blue and absorbing it till they be saturated. For this it is sufficient to heat an alkaline

alkaline lixivium upon Prussian blue till the alkali become unfit to discolour it. Alkali, when thus saturated with the colouring matter of Prussian blue, is found to have lost most of its properties. It is no longer caustic; it does not effervesce with acids; of the earthy salts, it decomposes only such as have barytes for their base; it precipitates all metallic salts; and this precipitation appears to take place by virtue of a double affinity, the affinity of the acid with the alkali, and the affinity of the metallic oxide with the colouring part of that salt. Alkali is thus capable of destroying the colour of a twentieth part of its weight of Prussian blue; and is then saturated with colouring matter. The acids disengage from it a small quantity of blue sediment; and the sulphate of iron is then instantly precipitated in perfect Prussian blue.

In regard to alkali prepared in the common way, Macquer observes, that it is far from being completely saturated with colouring matter; and that, from this circumstance, it produces at first a green precipitate from the solution of sulphate of iron. In fact, the portion of the alkali which is saturated does give a blue precipitate; but the portion which is not saturated precipitates iron in the state of ochre, which gives a green tinge to the blue precipitate, by intermixing the blue with yellow. According to this ingenious theory, the acid poured on the precipitate, serves to dissolve that portion of it which is not in the state of Prussian blue, and to improve the colour of that which is. The alum, which is added to the solution of sulphate of iron, saturates the alkali which is not already saturated with colouring matter; and the earth of this last added salt,

being precipitated with the Prussian blue, brightens its dye. As it is necessary to pour acid on the precipitate of sulphate of iron, in order to brighten Prussian blue, that acid may be added to the alkali before it be employed to precipitate the iron ; for while the acid saturates the pure part of the alkali, it does not combine with that which is impregnated with colouring matter, and is capable of instantaneously forming fine Prussian blue. This *phlogificated* alkali may be also saturated with bullock's blood, by digesting it over Prussian blue till it cease to discolour it: Macquer has recommended this alkali, saturated with acid, as a good test for determining the presence of iron in mineral waters : but M. Baumé has observed, that this liquor itself contains a certain quantity of Prussian blue, by which it may occasion mistakes when applied to this purpose. He proposes, therefore, to digest it for some time with a little vinegar, by a moderate heat, in order that it may deposit the blue matter which it contains. Such were the results of Macquer's ingenious experiments on Prussian blue ; but that celebrated chemist was himself very sensible of what was wanting, more especially to explain the nature of the colouring substance. He could not be persuaded to consider that substance as pure phlogiston ; for he could not conceive how, as is pretended in this hypothesis, iron, supersaturated with the phlogistic principle, could all at once lose both the property of obeying the attraction of the loadstone, and that of being soluble in acids, which, according to Stahl, this metal owes to its containing phlogiston. M. de Morveau, in his excellent dissertation on phlogiston, has made the first attempt to determine the nature of the colouring
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part of Prussian blue. He obtained, by distilling two drachms of this compound, twenty-two grains of a yellow empyreumatic liquor, which effervesced with alkaline carbonates, and communicated an high red colour to blue paper, but has not been once mentioned by Geoffroy or Macquer, though they likewise distilled Prussian blue.

M. Sage, in the year 1772, sent to the Electoral Academy of Mayence, a Memoir on *phlogisticated alkali*, in which he calls it animal salt. The lixivium of fixed alkali, treated with blood, and saturated by digestion on Prussian blue, as directed by Macquer, is, according to M. Sage, a neutral salt, formed by the animal acid with fixed alkali. It affords, by sensible evaporation, cubic crystals, either octohædral, or in prisms with four faces, terminating in pyramids having the same number of sides. This salt decrepitates on coals: by a violent heat, it melts into a semi-transparent mass, soluble in water, and proper for making Prussian blue. M. Sage thinks, that it is the phosphoric acid which neutralizes the alkali in this neutral salt; because, when the mixture of alkali with bullock's blood is made very hot, it melts, and exhales an acrid vapour, attended with white brilliant sparks, which, in his opinion, are nothing but phosphorus in flame: This opinion concerning the nature of the acid of the Prussian alkali would be established as a certain truth, if, on the one hand, it afforded phosphorus when distilled with coal, a phenomenon which in that case Prussian blue might likewise exhibit; and if, on the other hand, Prussian blue could be formed by combining phosphate of potash, or soda, with a solution of iron. But, as M. Sage has given no experiments

experiments to this purpose in his Memoir, his theory cannot be admitted.

The chemists of the Academy of Dijon have, in their Elements, adopted a part of this last doctrine: They consider the *phlogisticated* lixivium as a neutral salt. They recommend crystallizing it by evaporation, in preference to purifying it by vinegar, as has been proposed by M. Baumé. This salt, according to them, is very pure; when cast on nitre in fusion, it causes it to detonize. They say nothing of its decomposition, or the nature of its principles; they call it crystallized Prussian alkali,

Bucquet, on precipitating with muriatic acid, and afterwards filtrating a lixivium prepared for Prussian blue, observed, that the alkali, though apparently pure after this operation, and without any appearance of Prussian blue, yet deposited a blue powder. After filtrating it above twenty times in the space of two years, in order to separate the blue precipitated after each filtration, he at length found the liquor to be no longer capable of forming Prussian blue with the solution of sulphate of iron. I have kept by me for more than eight years, a small portion of this lixivium; during the two last of these years, it has given no precipitate, but has deposited a light bluish coating on the sides of the phial, and has maintained the same colour. I have had occasion to observe this phenomenon twice since I heard Bucquet mention it in his lectures: and I believe it to be inviolable. The Duke de Chaulnes showed Macquer a colouring lixivium, which, on being previously mixed with an acid, became incapable of affording Prussian blue. That chemist thinks, that the lixivium which exhibi

this phenomenon must have been prepared in metal vessels. Bucquet concluded from the facts which he is above mentioned to have observed, 1. That the Prussian blue is entirely contained in the alkali employed to precipitate the sulphate of iron : 2. That acids alone are sufficient to separate the alkali : 3. That when this alkali has, in the course of a certain time, deposited all the colouring matter which it contained, it is no longer fit for affording Prussian blue.

The *Journal de Physique*, for the month of April 1778, contains observations on Prussian blue, by M. Baunach, apothecary at Metz, which contribute greatly to support Bucquet's opinion. After describing the process of the German manufactories for preparing Prussian blue, M. Baunach affirms, that the lixivium prepared in those manufactories by the fusion of alkali, and the hoofs, horns, and hides of cattle, causes all metals, and even calcareous earth, to yield a blue precipitate. This alkali, after precipitating metals, dissolves them ; and they may be separated by the muriatic acid, when they will display a very beautiful blue colour. The singular facts related in that Memoir, such as the distillation of the Prussian blue produced by this lixivium, which affords neither oil nor ammoniac ; the solubility of the blue precipitate formed when muriatic acid is poured on this lixivium in nitric acid ; the circumstance of calcareous earth being found in the nitric acid which has destroyed the blue ; and the existence of a peculiar phlogisticated earth in it which he could not dissolve ; these facts, taken together, seem to suggest, that this blue is not of the same nature with that which is precipitated from ammon phlogisticated lixivium, which

which Macquer found to contain iron, and which can be produced only from blood.

Since these experiments on Prussian blue, Scheele has made a new series of researches on the nature of this composition, which, together with some observations of which I have not yet spoken, throw much new light on its nature.

1. Common Prussian blue, distilled by naked fire, affords a very large quantity of hydrogenous gas, together with oil, ammoniacal carbonate, and a little acid phlegm. This gas burns with a blue colour, like that which rises from marshes; its smell is empyreumatic: lime-water communicates to it the property of burning with a red flame, and detonizing in the air, for it absorbs from the lime-water part of its carbonic acid. M. de Laffone has considered the gas of Prussian blue as a peculiar inflammable gas. Prussian blue, after this analysis, is in the form of a blackish powder, subject to the attraction of the loadstone. M. de Morveau has observed, that it becomes orange before taking this colour. He is even of opinion, that Prussian blue, converted by heat to orange, might be advantageously employed in painting.

2. Ammoniac heated above Prussian blue decomposes it by seizing on the colouring matter, and leaving the iron in the state of brown oxide. Macquer made this fact known in the year 1752. Meyer, following him, has given the name of *tinging* liquor to this volatile alkali saturated with blue colouring matter, and recommends the use of it in analysing mineral waters. I have observed, that when caustic ammoniac is distilled on Prussian blue, the liquor which passes does not give a blue colour

to

to solutions of iron ; from which it follows, that the colouring matter is not so volatile as ammoniac. When only a part of this salt is extracted by distillation, the residue is of an olive green colour : on diluting it in distilled water, and filtrating the liquor, it is found to have impregnated the water with colouring matter ; and it accordingly affords a very lively Prussian blue with sulphate of iron.

3. In the year 1780, I discovered, that when lime-water is digested on Prussian blue, it dissolves the colouring matter, if assisted with a little heat. The combination is very rapid : the lime-water acquires a colour, and the Prussian blue takes the appearance of rust. This lime-water, when filtrated, is of a fine bright yellow colour : It does not turn syrup of violets green ; it has not an alkaline taste, and is not precipitated by the carbonic acid ; it does not combine with other acids : in a word, it is neutralized by the Prussian colouring matter ; and when poured on a solution of sulphate of iron, it affords a fine blue, which does not need to be brightened by an acid. Scheele has mentioned this Prussian lime-water, without knowing any thing of my experiments ; notwithstanding of my having given an account of the result in my *Elements of Chemistry*, printed in the year 1781. He is of the same opinion with me, that this combination is the very best that has been proposed for determining the presence of iron ; because it contains either none, or at least very little, Prussian blue completely formed.

5. The caustic fixed alkalis instantaneously destroy, in the cold, the colour of Prussian blue. I have observed that a pretty lively heat is produced on this occasion ; that the alkalis, when pure, discolour much more Prussian

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fian blue, than when saturated with carbonic acid ; and that they afford much more blue with solutions of iron, when pure, than when carbonated.

6. I found magnesia likewise to possess the property of discolouring Prussian blue, but not in so eminent a degree as lime.

7. Prussian blue in powder, if cast on nitre in fusion, produces some sparks ; from which we may infer, that it contains a combustible matter.

8. Prussian blue, prepared without alum, becomes, in a high degree, subject to the attraction of the loadstone, on being slightly calcined ; but common Prussian blue never acquires this property by the action of fire.

9. Prussian blue discoloured by alkaline matters, and in the state of oxide of iron, regains a part of its blue colour if an acid be poured into it. The cause of this phenomenon seems to be, that all the colouring matter has not been carried off by the first action of the alkalis ; and a portion is still retained among the particles of the oxide of iron.

All these facts show, that the colouring part of Prussian blue acts as a peculiar acid, which saturates alkalis, thereby forming neutral salts. This is the opinion of a great many chemists, particularly of Scheele, whose researches on this matter I am now to give some account of. That celebrated chemist has shown by his experiments, 1. That the lixivium of blood, or phlogisticated alkali, is decomposed by the carbonic acid of the atmosphere ; and that all other acids separate from it the colouring part. 2. That this colouring part is fixed, and retained in the lixivium, by a small quantity of pure iron, or sulphate of iron. 3. That when it is disengaged by

by acids, by means of distillation, it fills the balloons with a vapour which makes solutions of iron to yield a blue precipitate. 4. That when Prussian blue, or the lixivium of blood, is distilled entirely, it affords, together with the colouring matter, other products which alter this matter, such as sulphur; and that therefore the colouring matter cannot be obtained pure by this process. 5. That Prussian alkalis, distilled with sulphuric acid, precipitate a good deal of Prussian blue, and afford a liquor impregnated with the colouring matter: the blue precipitated in this operation depends on the iron dissolved in these triple salts, or compounds of alkali, colouring matter and iron. 6. That oxide of mercury, or red precipitate, carries off the colouring matter of Prussian blue by ebullition, in a quantity of water equal to twice the weight of the two substances; and that by distilling this mercurial Prussian lixivium with iron and sulphuric acid, the iron reduces the mercury after the acid has disengaged the colouring part: the colouring matter being dissolved in the water of the receiver as fast as it is disengaged, retains a portion of sulphuric acid: to separate it, Scheele mixes a little chalk with the colour, and distils it by a moderate fire; the colouring matter then passes very pure into the receiver: and as it is disengaged in the state of an elastic fluid, according to what has been observed by M. Monge, it may be received and dissolved in water with the tubes and the apparatus which we have already repeatedly described.

After these experiments on the affinities of the Prussian colouring matter, its obstinate adhesion to alkalis, and the means for obtaining it perfectly pure, Scheele, in a second Memoir, examines into the nature of this substance.

stance, and its combinations with alkalis and metallic oxides. Although his experiments are numerous, and very accurate, Scheele does not prove in this Memoir that the Prussian colouring matter is a peculiar acid : On the contrary, he endeavours to show, that it contains inflammable gas, ammoniac, and a carbonaceous principle. He acknowledges, however, that it renders a solution of soap turbid, and precipitates *hepars*, or alkaline sulphures; and, in a letter to M. Crell, he calls it the colouring acid. We give this substance the name of the *Prussic acid*, and call its saline combinations *Prussiates* of potash, soda, ammoniac, &c. In a note by the translator of Scheele, this acid is said to be decomposable by the acid of nitre; and a process of M. Westrumb's is likewise given for obtaining Prussiate of potash very pure. It consists in saturating caustic potash with colouring matter, digesting it over white lead, to purify it from any hepatic gas which it may contain, mixing it with distilled vinegar, exposing it to the sun, as directed by M. Scopoli and Father Bercia, in order to precipitate the iron entirely, and adding to it two parts of rectified alcohol. The Prussiate of potash is then deposited in bright lamellated flakes, washed with a new quantity of spirit of wine, dried, and dissolved in distilled water. Dr Crell says, that Scheele sent him, three months after M. Westrumb, an analagous process for obtaining a test liquor, the purity of which might be depended upon, to ascertain the presence of iron on any occasion.

The Prussic acid, or the colouring matter of Prussian blue, has likewise engaged M. Berthollet's attention, who has made still later experiments upon it than any of the above-mentioned chemists. Though this able philoso-

pher is not yet fully satisfied with his researches on this matter, they contain, however, a good many new facts and experiments, of such consequence as to render it proper for us to give here an extract from his Memoir, which he has obligingly communicated.

M. Berthollet first observes, that there are two kinds of Prussiate of iron ; the one common Prussian blue, the other Prussian blue that has lost a part of the acid which it possesses in its ordinary state. The last of these he calls *Prussiate of iron with excess of oxide*. Prussian blue is in this state, after being discoloured by an alkali. To separate this excess of oxide, he employs the muriatic acid, which dissolves it, leaving the Prussiate of iron in a neutral state. He observes, with M. Landriani, that when alkali is digested hot on Prussian blue, the alkaline Prussiate then formed, dissolves more oxide of iron than if the digestion had been performed with cold. Both of these chemists are of opinion, that an acid added to this triple combination combines with the excess of oxide of iron, and produces a precipitate of Prussian blue, just as when Prussiate of potash is mixed with a solution of iron. They say also, that heat causes this combination to yield a yellow Prussiate of iron, that is, with excess of oxide of iron. According to them, the acid added seizes the excess of oxide of iron, and the Prussian blue becoming then less soluble in the alkaline Prussiate, is of consequence precipitated. When the Prussiate of potash, prepared by a moderate heat, has deposited the Prussiate of iron with excess of oxide of iron, by ebullition, it may then be evaporated to dryness, dissolved again in water and mixed with acids ; but will not, by any of these expedients, be brought to deposit Prussian blue. M. Ber-

thollet says, that by evaporating the solution of Prussiate of potash thus purified, octahædral crystals are obtained with two pyramids truncated, so as to represent square plates with their edges cut sloping.

This chemist, on mixing a solution of these crystals with sulphuric acid, and exposing the mixture in a phial to the rays of the sun, observed, that in a short time a blue colouring matter began to appear, and was gradually precipitated till the mixture was entirely decomposed. A mixture of the same kind, preserved in a dark place, does not become blue, nor yield a precipitate, even though suffered to stand untouched for a number of months. A strong heat produces absolutely the same effect. From these experiments, M. Berthollet shows how inaccurate the principles on which the processes recommended for purifying alkaline Prussiates were founded. For, says he, instead of purifying them of a portion of Prussian blue, which chemists pretended to be only accidentally mixed in them, they decomposed most part of the matter which they attempted to purify. As Prussiate of potash is a triple salt, the Prussic acid has but a very faint disposition to adhere with potash, and may be separated from it by any other acid. When the extraneous acid combines with the potash, one part of the Prussic acid combines with the oxide of iron, to form Prussian blue, and the other is either volatilized in the state of acid, or reduced to its principles.

The iron precipitated by alkaline Prussiates retains, according to M. Berthollet, no small portion of these salts; by repeating washing, it may be purified of them: these lixiviums contain alkalis combined with a small portion of Prussic acid; and the Prussiates with excess of
alkali

alkali are not separated till after the excess of acid contained in the solution of iron is carried off by the first washings ; for the latter washings precipitate the iron in the state of blue from its solutions, which the first do not.

The only discernible difference which he has found between Prussiate of potash and Prussiate of soda is, that the latter crystallizes differently from the former. Mineral acids disengage the Prussic acid, which is in part fixed in the Prussian blue that is precipitated. This led Scheele to think of another combination, from which he might, with greater facility, obtain this acid pure, on which M. Berthollet has made some observations. This process, as we have already mentioned, consists in boiling red oxide of mercury with Prussian blue and distilled water. The Prussic acid then forsakes the oxide of iron, to unite with the oxide of mercury, with which it has a stronger affinity, and forms a soluble salt, which crystallizes in tetrahædral prisms, terminating in quadrangular pyramids, the sides of which correspond to those of the prisms. To this lixivium, after filtrating it, iron and concentrated sulphuric acid are to be added ; the iron unites with the oxigene of the mercury, and afterwards combines with the sulphuric acid ; the mercury is precipitated in a metallic state, as appears from its lustre. Scheele next distilled this mixture by a moderate heat, that he might volatilize only the Prussic acid ; but he observed, that, however moderate the heat which he employed, the Prussic was always mixed with a little sulphuric acid. To prevent this, he added to the mixture a certain quantity of chalk, to fix the sulphuric acid. Concerning this addition, M. Berthollet has observed, that, as Scheele

has not specified the quantity, this operation might very easily miscarry, if the chalk were ever so little above what is sufficient to saturate the sulphuric acid : for calcareous Prussiate must then be formed, which, by the law of double affinities, would decompose the sulphate of iron.

M. Berthollet has observed, that the sulphuric acid disengages but a small portion of acid from Prussiate of mercury ; and that it combines with the greatest part of that salt, without decomposing it, thus forming a triple salt, which crystallizes in small needles. According to his experiments, the muriatic acid disengages more of the acid of Prussiate of mercury than the sulphuric acid does ; forming, like it, a triple salt crystallizable in needles, and much more soluble than corrosive mercurial muriate. Alkalis and lime cause this triple salt to yield a white precipitate. M. Berthollet proves, that alkaline Prussiates do not precipitate barytes from its solutions, as Bergman thought, but join with the solution to form triple salts : he shows that they precipitate aluminous earth. The precipitate which they form with this substance suffers no alteration from the sulphuric acid ; but when digested with sulphate of iron, it forms Prussian blue.

The Prussic acid decomposes the oxygenated muriatic acid, and by absorbing its oxigene, becomes odorous. In this state it does not seem to have any great tendency to unite with alkaline substances ; for they scarce render its smell weaker. It no longer causes solutions of iron to yield a blue, but a green precipitate. The contact of the rays of the sun renders it blue again ; iron and sulphureous acid produce the same ef-

set upon it. The same phenomena appear when oxygenated muriatic acid, sulphate of iron, and Prussiate of potash, are mixed together. M. Berthollet concludes from this, that Prussian blue is liable to no alteration, either from light or from the sulphureous acid, and that it owes its green colour, solubility in acids, &c. to its having absorbed oxygen.

If the Prussic acid be supersaturated with oxygenated muriatic acid, and after that exposed to the rays of light, it assumes new characteristic properties. It no longer combines either with oxide of iron, or with water; but is found precipitated to the bottom of either of these liquors, in the form of oil, with an aromatic smell. If more oxygen be added to it when in this state, and it be now let exposed to the sun, it crystallizes in small white needles. This acid, thus oxygenated, is reduced to vapours by a moderate heat; these vapours are neither soluble in water nor combustible. M. Berthollet has not yet been able to determine what passes in this operation. Is the Prussic acid simply united with oxygen, without suffering any alteration? or is there one of its principles burnt? I am rather inclined to agree with him in adopting the last of these ideas: For though oxygen appears to adhere but feebly to the Prussic acid, yet the Prussic acid can no longer be restored to its original state, after being treated in this manner with the oxygenated muriatic acid.

The Prussic acid prepared for forming a green precipitate with iron, by means of the oxygenated muriatic acid, forms ammoniac whenever lime or an alkali is mixed with it. Though an acid be poured into this last mixture, yet it does not regain the peculiar odour of the

Prussic acid; from which M. Berthollet concludes it to have been destroyed by the mixture of the alkaline, or calcareous substance. Although the potash employed were perfectly pure, yet an acid poured in after it, produces an effervescence, and disengages carbonic acid.

From all these experiments, M. Berthollet concludes, that azote, hydrogen, and the pure coaly principle, combined in proportions, and condensed to a degree still unknown, form what is called the *Prussic acid*. The knowledge of this composition enables us to understand how the Prussic acid comes to be formed in animal matters, in certain vegetable substances, and in ammoniacal muriate contaminated with charcoal. It explains likewise the reason why this acid is so combustible, and detonizes with such force with various nitrates, why it affords ammoniacal carbonate by distillation, and why the same salt is formed in it on the addition of oxygenated muriatic acid. M. Berthollet doubts if this singular combination contains oxygen. At least, says he, if the Prussic acid *do* contain oxygen, it contains so very little, that the carbonaceous matter is not entirely reduced by it to carbonic acid; for Prussian blue affords, by distillation, a good deal of carbonated hydrogenous gas.

Such are the facts discovered by M. Berthollet. By ascertaining the nature of the colouring matter of Prussian blue, he has proved it not to be a genuine acid, however it may act as an acid in all its combinations. M. Vestrum and M. Hassenfratz have found in Prussian blue a little phosphoric acid. But the last of these gentlemen shows that acid not to be essential to its nature.

ture. M. Vaquelin and I have lately discovered, that the Pruffic acid is obtained by distilling the urinary calculus, and by treating many vegetable and animal substances with the nitric acid.

Sulphate of iron very easily decomposes nitre. The decomposition is partly owing to the sulphuric acid, which by combining with the alkali of the nitre, expels the nitric acid; but it is likewise owing in a great measure to the re-action of the iron on the last mentioned acid. If the sulphate of iron employed to decompose nitre be scarcely dry, a large quantity of nitrous acid is then obtained, very red and fuming: the residue, on being lixiviated, affords sulphate of potash, fixed alkali, and red oxide of iron, remaining on the filters. But if the sulphate of iron have been well calcined, and the nitre melted, the product obtained will then be very scanty. This product consists of two liquors; one of which being of a dark colour, almost black indeed, swims on the surface of the other, which is red and ponderous, like oil above water. Accordingly, M. Baumé considers this liquor as a kind of oil. There afterwards passes into the neck of the retort a white saline mass, which attracts the moisture of the atmosphere, and is speedily dissolved in water with heat, exhaling at the time a strong smell of spirit of nitre, and very thick red vapours. This solution, when saturated with potash, affords sulphate of potash. The white mass is therefore nothing but sulphuric acid, rendered concrete by a portion of nitrous gas.

There appears to be no difference between the heavy liquor in the balloon, and spirit of nitre obtained in Glauber's way. But the light liquor that swim

on being mixed with sulphuric acid, produces a lively effervescence, and even a dangerous explosion. Almost the whole of the nitrous acid is dissipated, and the sulphuric acid takes a concrete crystalline form. Bucquet, who communicated this discovery to the Academy, had at first observed, that this concrete acid, obtained by distillation, exhales red nitrous vapours when dissolved in water. He inferred, that the solidity of the acid must be owing to its containing nitrous gas. But to determine this with greater certainty, he attempted to mix the blackish brown nitrous acid, which swims above the red, with sulphuric acid highly concentrated. But at the very instant of the mixture, so rapid a motion took place, that the spirit of nitre poured on the sulphuric acid was expelled with noise to a great distance; and the person who made the mixture was covered all over with sulphuric acid; and there immediately appeared on his countenance a great many red inflamed pimples, which suppurated like the small-pox. The sulphuric acid became soon after concrete, precisely like that obtained by distillation, of which we have given the history. From this fact, it appears, that this acid may be rendered concrete, as well by nitrous as by sulphureous gas.

The residue remaining after the distillation of nitre by sulphate of iron calcined to redness, is nothing but scorix of iron, from which but very little sulphate of potash can be extracted by washing.

The solution of sulphate of iron suffers no alteration from hydrogenous gas. But though the base of this elastic fluid appears to have less affinity than iron with oxygen, as has been shown in the history of the decomposition

position of water ; yet M. Monnet has observed, that hepatic gas communicates to sulphuric mother-water the property of affording crystals : And Dr. Priestley has reduced brown oxides of iron by the contact of hydrogenous gas. These facts do not contradict our doctrine : they rather confirm it. In fact, iron may be deprived of whatever oxigene it contains above the proportion of 0,28 by the action of hydrogen ; but this proportion it obstinately retains, however attacked by that principle. Such is the reason why, in these instances of reduction, nothing is ever obtained but a black oxide, or martial *Æthiops*, and why iron oxidated by water is always black.

Alkaline sulphures precipitate sulphate of iron with a blackish colour. This precipitate is a kind of martial pyrites, or sulphure of iron.

The nitric acid is rapidly decomposed by iron, which disengages from it a good deal of nitrous gas, especially if the acid employed be concentrated, and the iron in a state of division. The metal is speedily calcined by the oxigene which it attracts from the acid of nitre ; the solution is of a brown red colour ; at the end of a certain time it is found to have deposited oxide of iron, especially if it have been exposed to the contact of air. On immersing into it a new quantity of iron, the acid, as has been observed by Stahl, dissolves it, and the oxide of iron, which it held in solution, is instantaneously precipitated. Yet by employing weak nitric acid and iron in small pieces, a more permanent solution may be obtained, in which the metal adheres with more obstinacy to the acid. This last combination is greenish, and sometimes of a bright yellow colour. Both these

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solutions,

solutions, when evaporated, become turbid, and deposit a brown red martial ochre. But if the latter be highly concentrated, instead of affording crystals, it takes the consistency of a reddish jelly, in part soluble in water ; the greatest part, however, being precipitated on such an occasion. On continuing to heat nitrate of iron, it gives out a good deal of red vapours ; and the magma, becoming dry, affords a brick-coloured oxide. This magma, when distilled in a retort, affords a small quantity of fuming nitrous acid, a good deal of nitrous gas, and some azotic gas. There can be no vital air obtained from it, because the iron retains all the oxygen of the acid. The oxide which remains after the distillation of nitrate of iron is of a lively red colour, and would make a fine colouring matter for painters, &c. The nitrous solution of iron, however highly saturated, has never, on any occasion, appeared to me liable to be precipitated by distilled water. The alkalis decompose it with phenomena diversified according to their different natures. Caustic potash makes it yield a bright brown precipitate: the mixture assumes very speedily a blackish brown colour, much deeper than that of the former solution. The cause of this phenomena is, that a portion, though a very small one indeed, of the precipitate is dissolved by the alkali. Carbonate of potash separates from it a yellowish oxide, which very soon takes a beautiful orange red colour. If this mixture be stirred in proportion as the effervescence takes place, the precipitate is again dissolved in much greater abundance than in that which is produced by caustic potash. M. Monnet has accurately observed this phenomenon, and he ascribes it with good reason to the gas, which is disengaged.

disengaged. This solution of iron by fixed alkali bears the name of *Stahl's alkaline martial tincture*. Its colour is a very beautiful red. M. Baumé advises to prepare it with a nitrous solution of iron, containing but a small portion of the metal. Stahl, again, recommended an highly saturated solution. M. Monnet has observed, that a yellow solution affords a copious precipitate, which is scarce dissolved again in alkali, and does not colour it like martial tincture; whereas a very red solution instantaneously forms a martial tincture with the same alkali. Stahl's martial tincture loses its colour in a certain time, and deposits the oxide of iron which it contains. It may be decomposed with the help of an acid. The acid of nitre separates from it a red brick-coloured oxide, which is soluble in acids, and is called *Stahl's aperient saffron of Mars*. Pure or caustic ammoniac causes the nitric solution of iron to yield an almost blackish deep green precipitate. Ammoniacal carbonate dissolves again the iron which it separates from the acid, and takes a red colour still more lively than that of Stahl's tincture. This solution of iron by ammoniacal carbonate, might be of great use in cases in which there is need both of a powerful tonic and an active discutient.

I have never been able to obtain more than a very small quantity of genuine Prussian blue from the red, saturated, nitric solution of iron, by alkali saturated with the colouring matter of that composition. I could never obtain any thing but a blackish precipitate, liable to be again dissolved by the muriatic acid: the liquor, on this last event, assumed a green colour.

M. Maret, secretary to the Academy of Dijon, has sent to the Royal Society of Medicine, a pro

king *martial Æthiops* very quickly. It consists in precipitating the nitric solution of iron by caustic ammoniac, and in washing and drying the precipitate without loss of time. M. d'Arcet, who was employed by the Society to examine M. Maret's process, did not uniformly obtain the same result. In my Memoirs on Precipitates of Iron, I have determined in what cases M. Maret's process must succeed, and when it is likely to fail. To obtain this *Æthiops*, it is requisite, 1. That the solution of iron have been lately formed, and that very slowly, of weak nitric acid, and iron somewhat divided, both cold. 2. That the ammoniac be recently prepared, very caustic, and, above all, have lost, by standing undisturbed for some time, the small portion of calcareous earth, and blackish combustible matters, which it usually carries up from the sal ammoniac and lime, if it be not extracted in Woulfe's apparatus. 3. That the precipitate be instantly separated from the liquor, and speedily dried in close vessels. Even when all these precautions are carefully taken, the precipitate is sometimes not very black, but rather of a light brown colour. It rises in scales, the under surface of which is blackish; a circumstance which proves, that the contact of air slightly rusts its upper surface. I have obtained a more beautiful and permanent *Æthiops*, by precipitating muriatic and acetous solutions of iron with fixed alkali and caustic ammoniac; washing these precipitates sufficiently, and then drying them speedily in close vessels. Yet I am of opinion, that these *Æthiops*, however pure they may be supposed to be, still retain a small portion of their precipitants and first solvents; as has been observed by M. Bayen of the precipitates of mercury; and they cannot therefore be employed in
medicine

medicine with so much certainty as those which I have above mentioned. M. d'Arcet, in his Report to the Royal Society of Medicine concerning M. Maret's process, has communicated a process of M. Crohare's, for making *martial Æthiops*. This apothecary, who is known by a number of judicious chemical operations, prepares *martial Æthiops* by boiling water acidulated with a little nitric acid, upon iron filings. The metal is immediately slightly oxidated, and affords a good deal of black oxide, or *martial Æthiops*. But in my opinion, M. Joffe's process is preferable to all of these; it is easily performed, and is attended with no danger.

As iron is often used in procuring nitrous gas, it cannot be improper to observe here, that the nature of this gas is never precisely the same on two occasions; it varies amazingly, according as the circumstances of the solution are diversified, as the acid contains more or less azote and oxigene, as the iron is more or less disposed to absorb oxigene, as the temperature of the matters is hotter or colder, &c. Gas prepared by this process generally contains more or less azote; for as iron absorbs a greater proportion of oxigene than most other bodies, and absorbs different quantities of it, according as it is more or less completely in a metallic state, the effects of nitrous gas disengaged by this metal are therefore more or less uncertain in eudiometric experiments. This truth, which is applicable to all bodies that separate nitrous gas from the acid of nitre, shows how little the essays of eudiometers with nitrous gas are to be depended upon. Alkaline sulphures are therefore

fore greatly preferable as tests for determining the purity of air:

The muriatic acid diluted in water dissolves iron rapidly. A large quantity of hydrogenous gas is disengaged from this solution, the production of which must be owing to the decomposition of the water, in the same manner as when the metal is dissolved in the sulphuric acid. The hydrogenous gas produced by the action of iron on the muriatic acid, was formerly thought to be different in nature from that which is disengaged from the sulphuric solution of iron. This elastic fluid was then thought to be one of the principles of the muriatic acid. But since the discovery of the decomposition of water by iron, it has been proved, that the water, and not the muriatic acid, the nature of which is still unknown, gives rise to the hydrogenous gas disengaged from the muriatic solution of iron; for the acid remains undiminished and unaltered after the exhalation of this gas, and the same quantity of alkali is necessary to saturate it which it would have been required before. This solution of iron by the muriatic acid produces a considerable heat; which continues to be felt till the acid be saturated: a portion of the iron is precipitated in real *Æthiops*, in this as well as in all its other solutions. When filtrated, it is of a green colour, inclining to yellow: It is much more permanent than either of the two former; when inclosed in a phial properly stopped, it deposits no oxide. I have kept by me some of it for eight years; in all which time it has deposited nothing but a very light pale yellow dust. But, again, when it is left exposed to the air, it deposits in a few weeks almost all the iron that it contains;

and the more it has been brought into contact with air, the brighter is the colour of the precipitate. It is at present known as a certain fact, that this precipitation, which is in the same manner produced in all the other solutions of iron, is owing to the metal absorbing the oxygen of the atmosphere; as I conjectured, and suggested to the public in the year 1777. (See my *Memoirs on Chemistry*.)

Stahl announced to the world, that in the combination of iron with the muriatic acid, the muriatic acquired the characteristic properties of the nitric acid. But this fact has not been observed by any other chemist. It appears that Stahl attended only to the yellow colour of this solution, and the smell which it diffuses; a smell in fact but little different from that of spirit of salt, and much the same as that of the oxygenated muriatic acid.

The solution of iron by the muriatic acid does not crystallize regularly when evaporated. M. Monnet has observed, that if left to cool, when its consistency is that of a syrup, it forms a kind of magma, in which flat needled crystals are observed, which are liable to deliquesce. This magma melts by a very moderate heat; when a stronger heat is applied, it is decomposed, but not so easily as nitrate of iron; and when dry, it takes the colour of rust. There is disengaged from it a portion of muriatic acid, which may be obtained by distillation; and which, as has been remarked by Brandt, carries off with it a little oxide of iron.

The Duke d'Ayen, in four excellent Memoirs on the combinations of iron with acids, which he has given the Academy, has entered into a minute examination
of

of what passes when muriate of iron is decomposed in a retort. He obtained from this operation very singular products: He first obtained, by a moderate heat, a phlegm slightly acidulated: the muriatic acid was then concentrated; and its gas, though much more volatile than water, was in part fixed by the iron. By a much stronger heat, a part of the acid was volatilized with a little iron, and some crystals, not disposed to deliquesce, were formed in the balloon. At the same time, there were sublimed to the upper part of the retort, a number of very transparent crystals, resembling razor-blades, which decomposed the light like the most beautiful prisms, displaying very beautiful shades of red, yellow, green, and blue. There remained at the bottom of the retort a stiptic, deliquiating salt, of a brilliant colour and a foliated form, precisely like that species of talc in large plates, which is improperly called *Muscovy glass*. This last salt, when exposed to a violent heat in a stone retort, was decomposed, and afforded a sublimated product of a still more surprising nature than any of the former products. It was an opaque matter, truly metallic in its nature, and when examined by the microscope, it exhibited regular crystals, or sections of hexagonal prisms, which the Duke d'Ayen compares to the square pieces of wood used in flooring rooms. Those crystals were as brilliant as the best polished steel, and equally subject to the attraction of the loadstone; this was iron partly reduced and sublimated*. Art seems, in this instance, to effect an imitation of

* I have in my cabinet a black iron ore, with small and very brilliant laminæ, half a line in breadth, the form of which nearly resembles

of nature, which sublimes black oxides of iron by the fire of volcanoes, in the form of bright polished plates like Steel. Such at least appears to be the origin of the specular iron of Mont d'Or and of Volvic; which, according to the accurate observations of M. de l'Arbre, physician at Riom, is always found in the chinks of lavas.

From these particulars, it appears what singular phenomena the science of chemistry offers to our observation, and what valuable discoveries it promises to such as shall pursue a train of experiments with the accuracy and perseverance of the Duke d' Ayen. Let it not escape us, that this reduction of iron favours the doctrine of gases, and that similar products might perhaps be obtained by the same process from many other solutions of metals.

The muriatic solution of iron is decomposed by lime and alkalis, like all martial solutions; but these precipitates are not so much altered, and may be very easily reduced, especially such as are produced by caustic alkalis. I have already observed, that this combination affords by precipitation the purest *Æthiops*, or black oxide of iron, that can possibly be obtained. Alkaline sulphures, sulphurated hydrogenous gas, and astringents, decompose this solution as well as the other two: lastly, Prussian alkalis, or alkaline Prussiates, cause it to yield a very beautiful blue precipitate.

Water

that of the crystals obtained by the Duke d'Ayen. They are very thin small scales, of a very sparkling grey iron-colour, disposed slope-wise, so as to intersect each other in all directions, and dispersed in a reddish opaque quartz, or a kind of coarse jasper. This beautiful specimen comes from Lorraine. The iron of Framont is of the same nature. F.

Water impregnated with carbonic acid easily dissolves iron : all that is necessary in order to accomplish this combination is to put iron filings into the acidulated liquid, and to leave the mixture to digest during a few hours. This liquor, after being filtrated, has a pungent, and somewhat stiptic taste. Messrs Lane and Rouelle have observed the carbonic acid to possess this property. Bergman calls this combination *aerated iron*, and says, that when exposed to the open air it acquires a rainbow-coloured pellicle ; that it is decomposable by pure alkalis : but that alkalis saturated with carbonic acid produce not the same effect upon it. This solution gives a green tinge to syrup of violets, and affords with calcareous Prussiate a very brilliant Prussian blue. When exposed to the air, or heated, it precipitates brown oxide of iron. The name which we give to this combination is *carbonate of iron*. Iron has a strong tendency to combine with the carbonic acid. In nature we often find it in this state. Muddy iron ores and sparry iron appear to consist mostly of this combination. Ferruginous mineral waters often contain iron in the state of carbonate of iron. This salt, when separated from the water, and dried, is scarce soluble in that fluid. But it dissolves plentifully in liquid carbonic acid ; subsiding, however, in a precipitate when the acid is volatilized. We know not in what manner the fluoric and the boracic acids act upon iron.

This metal very readily decomposes sulphuric salts, particularly sulphate of potash or soda. I have treated these salts with iron in a crucible, and have found them reduced by such treatment to the state of sulphures. The lixivium of a sulphure of this kind is of a very deep

green colour. A few drops of acid very speedily destroy the colour of this metallic tincture. The greatest part of the iron, oxidated by the oxigene of the sulphuric acid, remains undissolved in the water of the lixivium; and acids disengage from it a large quantity of sulphurated hydrogenous gas.

Iron causes nitre to detonize. On throwing into a red-hot crucible a mixture consisting of equal parts of iron filings and dry nitre, in a certain time a very rapid motion is excited, and a great many bright sparks fly out of the crucible. When the detonation is over, the crucible contains a reddish oxide of iron, of which a small part is combined with the alkali; when this matter is washed, the water dissolves the alkali, and the oxide of iron remains on the filter. This oxide was formerly called *Zwelfer's saffron of Mars*. It is of a reddish yellow colour, and is scarce soluble in acids. The alkali separated from it by washing is caustic, according to most chemists; for it is generally thought that metallic oxides act like pure lime on this salt, thus saturated with carbonic acid *.

Iron easily decomposes ammoniacal muriate. Two drachms of iron filings, triturated with a drachm of this salt, give out ammoniac gas. Bucquet, who distilled this mixture in a pneumatoc-chemical apparatus with mercury, obtained from it fifty-four cubic inches of acriform

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fluid;

* It is to be observed, that since Black's Theory, concerning the conductivity of lime and alkalis, has been received, the proper experiments have not yet been made to determine whether metallic oxides and lime, properly so called, agree in their phenomena in this respect. And, till experiment determine, we can say nothing certain on this head. A.

fluid; one half of which was ammoniac gas, and the other half hydrogenous gas. Four ounces of the same filings, with two ounces of ammoniacal muriate, afford, when distilled in a retort with a common receiver, about two drachms of liquid ammoniac, impregnated with a little iron, which it soon deposites in the state of oxide of iron. The residue of these operations is muriate of iron. What occasions the decomposition of ammoniacal muriate by iron is, that the metal eagerly combines with muriatic acid: a proof of which is the disengagement of hydrogenous gas, observed to take place during the operation. In pharmacy, there is a medicine prepared of ammoniacal muriate and iron, which is called *martial flowers of sal ammoniac*, or *ens martis*. A pound of ammoniacal muriate in powder is mixed with an ounce of iron filings: this mixture is exposed in an earthen pot covered with another vessel of the same kind to a fire sufficient to make the under-part of the apparatus red-hot. In five or six hours, there is a yellow matter sublimated, which is to be preserved in a phial: this matter is the *martial flowers*. This substance consists chiefly of sublimated ammoniacal muriate, with a little oxide of iron. As the metal very readily decomposes this salt, only a very small quantity of it must be employed, in order that the greatest part of the salt may be sublimed in its natural state. That portion of the oxide of iron which is volatilized, communicates a yellow colour to the ammoniacal muriate, which is at the same time sublimated.

Oxide of iron decomposes this salt better than the metal itself; for it disengages the ammoniac without heat. That which is obtained by distillation is very fluid, and sufficiently caustic. I have obtained ammoniac,

which gave a slight effervescence with acids, by distilling ammoniacal muriate with half its weight of *aperitive saffron of Mars*, or oxide of iron, prepared with access of air, and of consequence containing carbonic acid. In this instance, the carbonic acid disengaged from the iron combined with the ammoniac, and so rendered it effervescent.

Iron is altered in its colour by hydrogenous gas ; but the alteration which it suffers has not been yet sufficiently examined. Black oxide of iron is not decomposed by this gas ; but the brown or the red oxides easily are, and they then pass into the state of black oxide ; for hydrogen robs them of all the oxygen they contain, more than what is requisite to maintain them in the state of black oxide. Sulphur combines rapidly with iron. A mixture, consisting of iron filings and sulphur in powder, and moistened with a little water, becomes hot in a few hours. It then swells, acquires consistency, absorbs the water, bursts with a discernible crackling, and exhales a good deal of aqueous vapour, accompanied with a foetid odour, very like that of sulphurated hydrogenous gas. When the mixture is a large mass, it takes fire in the space of four and twenty or thirty hours, and as soon as ever the aqueous vapours cease to arise from it. When the substances have nearly ceased to act on each other, the heat rapidly increases, and inflammation takes place. The smell then becomes much stronger ; it seems to be owing to the hydrogenous gas produced by the action of the sulphur and iron on the water. This smell is mixed with another, that of alkaline sulphures and pure hydrogenous gas ;

the inflammation observed in this experiment is, no doubt, owing to a copious disengagement of hydrogenous gas ; for the flame is more lively than that of sulphur. It rises a foot high, according to M. Baumé's account, who observed this phenomenon on a mixture, consisting of an hundred pounds of iron filings, and as much sulphur in powder : it lasts only for two or three minutes ; the mixture continued red and burning for forty. M. Baumé explains this inflammation into the disengagement of the phlogiston of the sulphur into the state of free fire. Lemery, the father, has given the name of artificial volcano to this experiment. He imagined the fires which kindle in the interior parts of our globe, and by forcing their way to the surface, produce earthquakes and volcanoes, to arise from a similar combustion of pyrites piled on each other, and moistened by water. In his opinion, these awful phenomena might be imitated, by burying in the earth a mixture of sulphur in powder and iron filings, reduced to a paste with water, and covering it over with earth pressed closely down upon it. This experiment did not succeed with Bucquet, who repeated it with the greatest exactness. Dr Priestley seemed to show the reason why it failed. That philosopher observed, that the moistened mixture of sulphur and iron absorbed a certain quantity of air, which might be thought necessary to its inflammation. But, notwithstanding this, the inflammation takes place without the contact of air. It appears, in fact, that the iron being very much divided, re-acts on the fluid, and seizes its oxigene, by which it is calcined, and disengages the hydrogenous gas, which takes an elastic form by means of the heat separated from the water. This gas
also.



also dissolves a portion of the sulphur, and thus becomes sulphurated hydrogenous gas.

There is a strong analogy between this combination of iron and sulphur by the humid way, and the efflorescence of *pyrites*; which, when they are moistened by water, produce sulphurated hydrogenous gas.

Sulphur combines very easily with iron by fusion; the result is a sulphure of iron, or *pyrites* arranged in needles. As in this case the sulphur increases greatly the fusibility of iron, the metal may be instantaneously melted with the help of this combustible body. In order to this, a small bar of iron, heated to whiteness, may be applied to a roll of sulphur, and the melted matter which runs from them received into water. It will be found in the fluid in brittle blackish globules, resembling *pyrites*, and, like them, in the form of small slender concentric pyramids.

Iron with arsenic affords a brittle mixture, which is but very little known.

This metal appears to exist in many iron ores; and it is in consequence of being intermixed with it that iron is brittle when hot.

With cobalt, iron forms a metallic mixture, with small close grains, hard, and not easily broken.

It does not appear capable of combining with bismuth.

In combination with antimony, it forms a brittle alloy with small facets, which yields but very little to the hammer. Iron has more affinity than antimony with sulphur; and is of consequence capable of decomposing sulphure of antimony. To effect this decomposition, make five ounces of the points of horse-shoe nails red-

hot in a crucible; throw upon them a pound of pulverized sulphure of antimony; and apply speedily to this mixture a heat sufficiently strong to melt it: when it is pretty well melted, add an ounce of nitre in powder, to promote, by a thorough fusion, the separation of the scorizæ from the antimony; let the mixture be now left to cool, and the antimony will be found by itself not impregnated with any iron. If the mixture employed consist of one part of iron, with two of sulphure of antimony, the antimony will be alloyed with iron. The scorizæ which are found above antimony alloyed with iron, and prepared with nitre and tartar, are of a yellowish colour like amber, which they owe to the iron contained in them, Stahl has, on this account, called them *succinated scorizæ*. He directs to reduce them to powder; then boil the powder in water, which carries off the most subtle part of it; decant off the liquor; filtrate it; and detonize the powder remaining on the filter three times with nitre; then wash and dry it. and the matter thus prepared is Stahl's *aperitive saffron of antimoniated Mars*.

It is still uncertain whether zinc be capable of entering into union with iron. Malouin, in his *Memoir on Zinc* (*Academy*, 1742), has shown, that this semi-metal may be applied like tin to the surface of a piece of iron, so as to secure it from the contact of air; a circumstance which shows, that these two metallic matters are capable of entering into combination with one another.

It appears that nickel enters into a very intimate union with iron; for, as Bergman has shown, these two metallic substances can never be entirely separated.

Mercury can contract no union with iron in its metallic state. Ineffectual attempts have been made to produce a direct combination of these two substances; but their oxides have been combined. Navier has observed, that a snowy white precipitate may be obtained by mixing together a solution of iron and a solution of mercury, both made by the fulphuric acid; and on evaporating this mixture, small flat crystals are formed in it, very thin, and resembling the boracic acid. Navier is convinced that these crystals are a combination of iron with mercury.

Lead cannot enter into union with iron.

It appears that iron and tin may be combined by fusion. That art which consists in coating the surface of iron with tin, or preparing white iron, shows this combination to be possible. The surface of iron to be tinned must be smooth and sparkling. For this end, it is sometimes cleared with an acid, sometimes filed, and sometimes coated with sal ammoniac: when prepared in this manner, it is immersed vertically into a vessel full of melted tin; its position in the vessel is repeatedly changed, in order to bring it more completely in contact with the tin; and when it is thought to be sufficiently tinned, it is taken out and rubbed with saw-dust or bran, to clear it from the tallow or pitch with which the surface of the melted tin is covered, and which of consequence sticks to the surface of the tinned iron. If the iron subjected to this process be in very thin plates, the tin will not barely adhere to its surface, but penetrate through it, and combine with all its parts: and on cutting or breaking it, the same white colour will appear in the midst as on the surface of the plate: From which

it appears, that white iron, properly prepared, is actually a chemical combination. Besides, it is more malleable than iron, and is wrought into vessels of a form which it would be impossible to make the pure metal take with the hammer.

We have seen, in the beginning of this chapter, that iron easily absorbs carbone by heat, forming, by its union with that combustible body, cast iron and steel; with this difference between these two compounds, that in the former oxigene is contained, but not in the latter. In both, the quantity of the iron is much above that of the carbone. Scheele, who has applied chemical analysis to so many happy purposes, found, on investigating by this method the nature of *plumbago*, a species of mineral, the rank and character of which naturalists were long at a loss to determine, that it is nothing but a natural combination, consisting of a large quantity of carbone, with a very small proportion of iron.

Plumbago has been long confounded with *molybdena**. Pott was the first who proved that neither of these substances contains lead, as they were anciently thought to do. The names bestowed on *molybdena* and *plumbago* were formed to perpetuate the error. They were both indifferently called *lead ore*, *English pencil*, *marine lead*, *black ceruse*, *painter's mica*, *lead pencil*, *false galena*, *talc*, *blende*, *potelot*.

Native *carbure of iron* (a name which, as expressive of the nature of the compound, we have substituted instead
of

* It is now agreed, that the substance called *molybdena* is the oxide of a certain acidifiable semi-metal. Its history has been given among the semi-metals. F.

of *plumbago*) is found in mountains, frequently among beds of quartz, feldt-spar, clay, or chalk, in the form of irregular round lumps, or balls, like the testicles of animals of various sizes; the largest weighing from eight to ten or eleven pounds; sometimes, too, it is scattered in much smaller fragments; and sometimes even in strata or layers. The inhabitants of Bleoux, a hamlet near Carban, in the higher part of Provence, work *native carbure of iron*, or *plumbago*, which is found in strata of the thickness of four feet, between two beds of clay; the matter is sold at Marseilles. M: de la Peyroux reckons carbure of iron among the minerals of the Pyrenees: it is found in Spain and in Germany; in the dachy of Cumberland in England, there is a very rich mine of it; it is made into pencils, which are much esteemed. North America, and the Cape of Good Hope, likewise afford specimens of this substance. *Plumbago* has for some time been found in octohædral crystals.

Carbure of iron is of a glittering blackish blue colour; it feels greasy, and its fracture is tuberculous; whereas, *stibdena* has a lamellated fracture. Its being of an unctuous soapy nature, has induced some chemists to consider it as a kind of impure clay. It spots the hands; and the *black pencil* leaves, as every body knows, a blackish mark on paper.

Carbure of iron suffers no alteration from heat in close vessels. M. Pelletier, who has made a series of experiments on this substance, since Scheele, without obtaining, however, any different result, exposed 200 grains of it in a well-stopped crucible of porcelain, to the heat of the fire used in the Sèvres manufactory for porcelain;
the

the mineral lost only ten grains : But when heated in contact with air, it burns and is oxidated, so as to leave scarce any residue. Messrs Quist, Gahn, and Hielm, observed, that 100 grains, treated in this manner, in a capsule under a muffle, left only ten grains of ferruginous oxide. This oxidation is a slow combustion, very difficult to bring about. It does not succeed in a common crucible : but to effect it, a thin piece of carbure of iron must be exposed in a broad flat vessel to the action of a strong fire, and the surfaces often cleared, and its position changed.

Neither air, water, nor any earthy substance, acts on carbure of iron. The alkalis act powerfully on this substance. If one part of carbure of iron, with two of dry caustic fixed alkali, or the *lapis causticus*, be heated together in a retort with a pneumato-chemical apparatus, the small quantity of water still contained in the salt contributes to the combustion of this substance ; a product of carbonated hydrogenous gas is obtained ; the alkali is found to be saturated with carbonic acid ; and there remains scarce any of the carbure of iron. The result of this experiment, and the detonation of carbure of iron with nitre, which will hereafter come under our notice, led Scheele to consider this matter as a kind of sulphur formed of *aerial*, or carbonic acid and phlogiston. We will examine this theory, after having considered the other phænomena which this combustible body displays when exposed to the action of acids and neutral salts.

The sulphuric acid, according to Scheele, is incapable of acting on carbure of iron. M. Pelletier has observed, that when 100 grains of this substance, and four

ounces of concentrated sulphuric acid, are digested together cold for several months, the acid acquires a green colour, and becomes liable to congeal by a very moderate degree of cold. This acid, when distilled on carbure of iron, passes into the state of sulphureous acid, in consequence of the combustion of a part of that substance.

The nitric acid produces no alteration upon it. The muriatic acid dissolves the aluminous earth and the iron, and serves to purify it, according to M. Berthollet: M. Pelletier has made use of the same process in order to obtain pure carbure of iron. With respect to the aluminous earth, which the muriatic acid carries off from carbure of iron, Scheele remarks, that the aluminous earth separated in his analysis, belonged to the crucible in which he had before treated it.

Carbure of iron, when melted with four parts of sulphate of potash, or sulphate of soda, affords alkaline sulphures, and is entirely decomposed.

Nitre detonates with the help of this substance; ten parts of that salt are requisite to burn one of carbure of iron. The fixed alkali which remains after this operation gives a lively effervescence with acids, and is found to be mixed with a small quantity of oxide of iron. The same effect takes place with nitrate of soda and ammoniacal nitrate. M. Pelletier has observed, that in this last operation there is ammoniaic disengaged in combination with a portion of carbonic acid.

Carbure of iron acts neither on muriate of potash nor muriate of soda.

When distilled with ammoniacal muriate, it gives *partial ammoniaic flowers*. When it is heated with sulphur

fulphur in a retort, the sulphur is sublimed by itself, without producing any alteration on the carbure of iron.

All these facts concur to prove, that this substance is neither earth nor lead ore, as it was thought to be. But Scheele's Theory, again, who considers it as a combination of carbonic acid with phlogiston, cannot be admitted, 1. Because that chemist has not informed us what quantity of the acid he obtained; 2. Because he could not compose *plumbago* artificially, by combining carbonic acid with a combustible matter. Besides, the two substances with which Scheele changed carbure of iron into carbonic acid, effect the change by affording vital air, which combines with the inflammable matter of this substance, and gives rise to that acid by the fixation of oxigene; for in this manner does the nitric acid convert tungsten, arsenic, and sugar, into acids. With regard to caustic fixed alkali, which likewise changes carbure of iron into carbonic acid, this effect is plainly owing to the water which that alkali always contains, and which burns the combustible matter in the same manner as it consumes zinc and iron; the hydrogenous gas obtained during the re-action of the alkali and the carbure of iron adds confirmation to this theory. It might be still farther confirmed by passing water in vapours upon this substance, made red-hot in a copper or porcelain tube, as is done with iron and zinc. Although this experiment has not been yet made, I believe I may venture to advance, that the whole of the carbure of iron would be destroyed, and converted into carbonic acid, and that the product of the operation would be carbonated hydrogenous gas, mixed with a
large

large proportion of carbonic acid. It would then seem a natural inference, that the carbonic acid is a compound of plumbago and oxigene; but as we know from many other experiments, that this acid cannot be found unless when a combination of carbone and oxigene takes place; we must infer, in this instance, that *plumbago* contains a large proportion of carbone, and even consists almost entirely of that combustible body. A few facts concerning the properties of carbone, here thrown together, will further confirm this assertion.

The carbone or coal of various vegetable matters is brilliant, and has a metallic aspect, like carbure of iron; it soils the hands, and marks paper like that matter; and its texture too is granulated and brittle. The most brilliant coals, such as those of some animal substances, are as difficult to burn as carbure of iron, which needs to be much stirred, exposed to an intense heat, and brought as much as possible into contact with air, in order that it may be consumed; iron is found in both; And lastly, these two substances are both liable to be changed into carbonic acid by combustion. After considering these facts, may we not regard *plumbago* as coal formed in the interior parts of the globe, or buried in the earth? May we not even conclude, that this matter is formed by the combination of some mineral principles? though almost all chemists be of opinion, that nothing but organic matters can be converted into coal. But this notion can be confirmed or refuted only by a regular inquiry into the state of carbure of iron in nature, the circumstances of its formation, and the alteration which it suffers. Since the researches of Messrs Vandermonde, Monge, and Berthollet, into the several states in which iron subsists, discovered

discovered these facts concerning carbure of iron, they have farther discovered, that there is constantly formed, on the fusion of cast iron, a substance precisely similar to native carbure of iron. The ladles with which the cast iron is taken out to cool are usually coated with it. Masses of it are likewise found in crystals in repairing the upper parts of the furnaces. We may venture to hope that it will be one day artificially prepared for the service of the arts.

Carbure of iron is a good deal used. It is made into pencils; the most esteemed of which come from England. Kewick, in the county of Cumberland, is the place where that used for pencils is found. The native lumps are sawed into small slender pieces; which are put into wooden cylinders with grooves, and cut so that the cavity of the cylinder may be entirely filled. The dust produced from the sawing and cutting of the pieces inserted into the cylinders is used for pencils of an inferior quality, a great many of which are sold at Paris. It is mixed with a gum paste, or melted with sulphur. These base pencils are known in England, either by their melting and burning at the flame of a taper, or by their separating into bits, and even falling into powder when steeped in water. The German carbure of iron is likewise used for pencils: in making them, several extraneous matters are added; such as coal, sulphur, &c. In England the finest dust of carbure of iron is used for coating the wheel-work of some instruments; and it facilitates their motions by its greasy unctuous nature*.

One of the most important uses to which this substance

* This substance is likewise used for blackening the outsides of *refiners*. Its common name is *woad*. H.

stance is applied is to coat iron, in order to preserve it from rusting; the pipes of stoves, the back parts of grates, and other utensils exposed to the action of fire and air, are coated with powder of carbure of iron, which is applied to their surface by simply rubbing with a brush. Homberg, in the year 1699, described a process for giving a leaden colour to utensils of iron. It consists in mixing eight pounds of melted animal fat, with four ounces of camphire, and a sufficient quantity of carbure of iron, and laying this composition on iron so hot that it can scarce be held in the hand: these utensils must be carefully wiped with a cloth, after being covered with this sort of varnish.

The workmen who manufacture lead for hunting-shot, polish and blacken its surface at the same time by rolling it in powder of carbure of iron. It is likewise a part of the composition put upon the pieces of leather used for strapping razors. Lastly, it is used in the manufacture of several black English earthen wares; and in that of the crucibles which are made at Passaw in Saxony.

M. Pelletier, who has given a good account of the various uses to which carbure of iron is applied, found it to answer very well in a luting which he prepared after Pott, with one part of this substance, three of common clay, and a little cow-dung, reduced very small. This luting supports glass retorts well enough: they even melt sometimes without its suffering any change of form.

The principal uses of iron are so extensive, and besides so well known, that it is unnecessary to insist on them here; only we may mention, that no art can do entirely without it, and that it is, as Macquer says, the soul of all the arts. The various modifications of which

it is susceptible, render it very suitable for all the purposes to which it is applied. Cast iron is run into utensils more or less solid, and capable of resistance, according to the purposes for which they are designed. The tenacity and hardness of the several species of forged iron render it very suitable for all the purposes to which it is applied. The same is the case with the several kinds of steel. The fineness of the grain and the temper vary so as to divide it into a great many species, each of which is better fitted than any of the rest to some purpose or other in the circle of the arts. Oxides of iron serve for giving a red or brown colour to porcelain, pottery, enamels, &c. They are likewise employed in the preparation of artificial precious stones, and mixed with oil for painting colours.

Iron affords a remedy of great use in medicine; to which indeed the art is frequently indebted for success. This is the only metal that has no noxious quality whatever, and of the good effects of which there can be no doubt. There is even, as we have seen, such an analogy between iron and organic matters, that it seems to compose a part of them, and to be often produced by the operation of the vital powers of animals, and by vegetation. The effects of iron on the animal œconomy are various. It stimulates the fibres of the membranous viscera, and appears to act more especially on those of the muscles, which it affects as a tonic. It fortifies the nerves, and communicates to the animal, when enfeebled and languid, new force and vigour in a remarkable degree. It excites many secretions, especially such as take place by evacuations of blood or urine. It contributes to bring on natural hæmorrhages, such as the menstrual flux and the hæmorrhoids.

It increases and multiplies the contractions of the heart ; and of consequence renders the pulse quicker and stronger. It acts with no less energy on the fluids. It passes easily into the channels through which the blood circulates, combines with it, and thus gives it new density, consistency, and colour, and renders it more liable to concretion. It at the same time communicates to it such activity, that it passes without difficulty into the smallest vessels, stimulates of itself the sides of the ducts through which it flows, and thus conveys life and vigour through the whole system. The valuable experiments of M. Menghini, published among the Memoirs of the Institution of Berlin, prove, that the blood of people who make use of iron is higher coloured, and contains more than the natural quantity of this metal. Lorry, who, in the practice of medicine, has displayed that nice acuteness of observation, and that extension of views which distinguish the profound and philosophical physician, observed the urine of a sick person to whom he had administered iron reduced to powder, to take a manifest colour from an infusion of nut-gall. This metal is therefore tonic, strengthening, stomachic, diuretic, alterative, incisive ; and in the single operation of this medicine are united the virtues of a great number of drugs. It contracts the fibres like astringents, it increases their oscillation : and it has the superiority over many of the other medicines which possess the same virtues, as being more constant and durable in its effects ; for it combines with the organs themselves, by means of the fluids by which these are nourished. It may be usefully administered, therefore, in all cases in which the action of the

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fibres of the viscera, of the muscles, or even of the nerves, is very feeble ; when the stomach and intestines are so languid as to refuse their functions ; and in the case of weakness arising from such a cause : in short, whenever the consistency of the fluids is diminished, and they are become too thin, as in the green sickness, and in tendency to dropsy, &c. It is used under many different forms ; such as levigated filings, martial *Æthiops*, astringent and aperitive saffron of Mars, Stahl's alkaline martial tincture, martial flowers of sal ammoniac, &c. To these medicines might perhaps be added iron precipitated from acids, and again dissolved by ammoniac ; Prussian blue, the use of which as a medicine, is proposed by the chemists of the Academy of Dijon, &c. Sulphate of iron is applied externally to stop hæmorrhages, &c.

Iron, endowed with magnetic qualities, or artificial loadstone, has been thought to produce some very singular effects on the animal œconomy. According to many modern authors, when laid upon the skin, it eases pain, stops convulsions, occasions redness, sweating, and often, too, the eruption of small pimples ; it likewise renders epileptic fits less frequent. We are even assured, that in the space of twelve hours it communicates to water a purgative quality. These assertions, which it is pretended are justified by facts, afford so many proofs to enlightened philosophers of the difficulties with which the study of animal physics is attended. As no body is liable to be affected by the magnetic powers of other bodies which is not itself capable of acquiring such powers, it must therefore be impossible for the loadstone to act by virtue of its magnetic powers upon the animal œconomy.

economy. The physicians who ascribe to it such eminent effects, and such energetic medicinal powers, have been misled and deceived by the changes, more or less sensible, which have taken place about the time of the application of the magnetic body, and have been owing to the circumstances of the case, and the happy exertions of nature. This opinion is farther enforced by considering, that nature seems to act with more irregularity and inconstancy in removing pains and convulsions, than in any other instance; and that the medicinal virtues of the loadstone are chiefly inferred from the effects which have followed after applying it in cases of this kind.

To this very elaborate and complete chapter upon *iron*, very few facts can be added.

M. Chaptal says, that the cubic foot of iron, weighs not 880 *lib.* as our author alledges, but only 845 *lib.* Its specific gravity is 72.070. Iron ochres, supposed to be formed by the natural decomposition of pyrites, are the principal matter employed for dyeing *stuffs* with the various shades of *brown-red*. They are for this purpose calcined. At Maz-Dieu, near Alais in France, a stratum of ochre has been found, which affords an inimitable *red*. At Carron in Stirlingshire, in Scotland, and by Messrs Cooper and Barker, between Leith and Edinburgh, many articles of furniture, &c. are very ingeniously moulded out of crude iron. H.

C H A P. XIX.

Of Copper.

COPPER is a metal, of a very brilliant red colour, to which the alchemists gave the name of *Venus*, on account of the readiness with which it combines so as to suffer alteration from a vast variety of other bodies. It has a disagreeable smell, which is felt when it is rubbed or heated. Its taste is stiptic and nauseous, but less sensible than that of iron. It is hard, very elastic, and very sonorous. Its ductility is considerable: it is reducible into very thin plates, and very slender threads. In the hydrostatic balance, it loses about an eighth or a ninth part of its weight. Such is its tenacity, that a thread of copper, one-tenth of an inch in diameter, supports 299 1-4th pounds weight without breaking. Its fracture appears as if it were composed of small grains. It is susceptible of a regular form. The Abbé Mongez defines its crystals to be quadrangular pyramids, sometimes solid, and sometimes consisting of other smaller pyramids, inserted laterally.

Coppe

Copper is found in various states in the earth. Its ores are very numerous; but they may be all reduced to the following.

1. Native copper of a red colour, malleable, and possessed of all the other properties of the metal. It is distinguished into two sorts; copper of the first formation, and copper of a secondary formation, or cementation. The copper of the first formation is dispersed in plates or filaments within a gangue, which is almost always of a quartzose nature. It is sometimes found in octahedral crystals, one above another, resembling a kind of vegetation. There are other specimens in masses and grains. Copper of cementation is commonly in grains, or in thin laminæ on the surfaces of stones or iron. That which is found on iron appears to have been deposited in waters containing sulphate of copper, and precipitated by iron. Native copper is found in many places over Europe: At St Bel in the neighbourhood of Lyons, at Norberg in Sweden, at Newfol in Hungary, and in several parts of America*.

2. Copper oxidated and mineralized by the carbonic acid. There are several varieties of native carbonate of copper.

Varieties.

A. Red copper, or *hepatic copper ore*. This ore is distinguished by its dark red colour, like the colour of the scales which fall off from copper made red-hot, and then struck with a hammer. M. Monnet considers this ore as a natural

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* Also in different places in England, Scotland, and Wales, at Haindorf in Thuringia, &c.

Varieties.

tural oxide of copper: It is generally mixed with native copper and *mountain green*: it is not very plenteous; sometimes it is found in octahædral crystals, or silky fibres called *flowers of copper*.

- B. *Earthy copper, mountain green, or green chrysocola*. This ore is a genuine oxide of copper, of a lighter or a deeper green, not heavy, and unequally dispersed within its gangue. It appears from the analysis of the malachite, made by the Abbé Fontana, to be combined with carbonic acid. This ore is sometimes very pure. It may be considered as existing in three different states.

Simple *mountain green*, earthy or impure, called also *green chrysocola*.

Mountain green in crystals, or *silky copper* of China. This ore, which is common enough in Vosges and Hartz, is likewise found in China. It is pure, and crystallized in long silky bundles of no small solidity.

Mountain green in stalactites, or *malachite*. This substance, which is found in considerable abundance in Siberia, consists of layers in the form of nipples, of various sizes: some of the specimens consist of needles converging towards a common centre. The different layers have not all precisely the same shade of green. The malachite is hard enough to take a fine polish, and various toys are made out of it; but as it is often porous, and full of unequal cavities, it

Varia.

the solid pieces are always the most valuable when they come up to a certain size.

C. *Mountain blue*, or *blue chrysocola*. This is an oxide of copper of a deep blue colour; it is sometimes in a regular form, and in rhomboidal prismatic crystals of a very beautiful blue. It is then called *copper azure*. At other times, it is found in small grains, deposited in the cavities of different gangues, more especially in quartz. Generally, however, it is in thin layers, in the cavities of grey and yellow copper ores. It appears, that all these oxides of copper have been precipitated from sulphuric solutions of this metal by the intermedium of calcareous earths, through which the waters containing them flow. M. Sage considers these blue copper ores as combinations of copper with ammoniac; and says, that they differ from it only in being insoluble. He likewise thinks, that the malachite is nothing but this blue, which he calls transparent azure copper ore, with a small alteration. But this opinion is not generally received among the mineralogists. M. de Morveau thinks, that the blue differs from the green oxide of copper only in containing a smaller proportion of oxigene.

The blue oxide of copper seems to be the matter which colours certain stones; the turquois stone particularly, in which Reamur found copper, appears to owe its colour to this cause, as well as the Armenian stone, the

Varieties.

base of which is calcareous carbonate, or sulphate of lime. Mr Kirwan makes a species of copper ore of these blue stones. The turquoise is formed of animal bones, coloured by copper. According to Reamur, the Persian turquoise is not liable to suffer from the attacks of the nitric acid. The same acid entirely dissolves the turquoise of Languedoc.

3. Copper mineralized by the muriatic acid and combined with clay. M. Werner speaks of this ore in his translation of Cronstedt. It has been confounded with talc; and a person of the name of *Dans* exposed it to sale at Paris in the year 1784, under the name of *green mica*. It is in small crystals of a beautiful green colour, or in small sparkling scales. Mr Forster found specimens of this in the mines of Johan Georgenstadt. The green copper sand brought from Peru by M. Dombey seems to belong to this species of copper ore: on analysing it, I have found it to contain a little muriatic acid.

4. Copper mineralized by sulphur almost without iron. It is called *vitreous copper ore*; but the name is very improper. It is dark-grey, violet, brown, greenish, or entirely brown and liver-colour. A very moderate heat melts it. It is ponderous, sometimes flexible, and always of such a consistency, that it may be cut with a knife. In its fracture it appears brilliant like gold. It is one of the richest copper ores; for it affords no less than 90 pounds of copper in the hundred weight.

5. Copper

5. Copper mineralized by sulphur with more iron than is contained in the species immediately preceding; azure copper ore. It differs from the last only in containing about 30 pounds to the hundred weight: it affords only from 50 to 60 pounds of copper in the hundred weight; the rest is sulphur. These two ores may be assayed by acids.

6. Copper mineralized by sulphur with a good deal of iron; brilliant or yellow golden pyrites. The quantity of the sulphur and the copper varies greatly in this ore; the iron is always in a very considerable proportion. It exists in the earth in veins more or less considerable. This ore is sometimes massy and dark, often scaly, and seemingly micaceous. Such is the form of that of Denmark, Norway, Sweden, and St Marie-aux-Mines. On other occasions, this ore is dispersed in its gangue, as the copper of Alsace; it is then called *speckled copper ore*. This variety is often mixed with a little azure; coppery pyrites exhibit very brilliant colours on their surface, either blue or violet, which are owing to the decomposition of their principles. They are then called *copper with a waving light*, or *peacock-tail copper ores*. They usually contain a great quantity of sulphur, a little iron; and in copper they are not very rich. When these ores are only superficially dispersed on the gangue, they are more particularly distinguished by the name of *copper pyrites*: Of which kind are the ores of Derbyshire in England, some of those of St Bel in the Lyonnais, and a number in the mines of Alsace, as at Caulenbach and Feldens. They are besides found adhering to gangues of all sorts, rock-crystal, quartz, par, schistus, and mica, &c.

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tains from 14 to 20 pounds of copper in the hundred weight.

To assay a copper ore, after being pounded and washed, it must be subjected to long roasting by an intense heat, and melted with four times its own weight of black flux and marine salt. The button thus obtained, which is often blackened with a residue of the sulphur, is next to be melted with four parts of lead, and passed into a cupel, where the silver and gold which it contains may be separated; for there is but very little copper which does not contain some portions of these precious metals. M. Tillet's flux, which is a mixture of two parts of pounded glass, with one of calcined borax, and an eighth of coal, succeeds better in reducing this metal than black flux; for the black flux forms an alkaline sulphure, which dissolves a part of the oxide of copper.

Bergman recommends the sulphuric and the nitric acids for assaying copper ores in the humid way. When the copper has been dissolved by the acids, it is then precipitated by iron.

In working copper ores in the great way, they are first pounded and washed; they are then roasted at the first in the open air, and almost without wood; for when the sulphur which they contain, is once kindled, it burns away of itself. When it ceases to burn, the ore is then roasted anew, and even twice successively on wood, in order to obtain what is called *the mat of copper*. This is the ore after it has lost only a portion of the sulphur which it contained. The fusion to which it is subjected serves to make it expose its surfaces more entirely to the heat; in consequence of which it

is more thoroughly roasted. It is exposed to six or seven successive roastings, according as it contains more or less sulphur, and is then melted into *black copper*. This copper is malleable: still, however, there is so much sulphur united with it, which cannot be separated without extracting at the same time the perfect metals which it contains. The black copper is melted with three times its quantity of lead, which is called *refreshing the copper*; and this mixture is moulded into the form of loaves, which are called loaves of *eliquation*. These are instantly placed on two plates of iron, inclined so as to leave a gutter between them. They terminate immediately over the furnace of eliquation; the under part of which slopes forward. The fire under the plates heats the loaves: the lead melts, and runs under the coals, carrying with it the silver and the gold, with which it has a greater affinity than with copper. After this operation, the cakes are found to be considerably diminished, and to have lost their shape. They are now exposed to a stronger fire; the heat of which is so intense as to melt the copper, so far that it may be entirely separated from the lead. This third operation is called (in French) *réffuage*. The lead, with the perfect metals, is taken to the cupel. As to the copper, it is refined by melting it in a crucible, and suffering it to stand so long melted, that it may throw up, in a scum, any extraneous matters which it contains. It is assayed by dipping into it iron rods, which take up a little copper; and from its being more or less of a bright red colour, a judgment is formed of the purity of the metal. Copper thus refined is run into plates, or divided into *rosettes*. To form a *rosette*, the
scoriæ

scoria with which copper in fusion is covered are carefully taken off. The surface of the metal is suffered to settle and fix: when it ceases to be fluid, it is swept over with a wet besom: The impression of cold contracts it. The portion congealed separates not only from the edges of the crucible, but likewise from the rest of the melted metal, and is taken off with pincers. Most part of the copper in the crucible is thus taken off in *rosettes*. What remains at the bottom is called *the king*.

Cupreous pyrites, containing but little of the metal, are wrought solely for the sulphur and the vitriol. At St Bell, and in many other places, they are roasted and distilled, in order to separate the sulphur. During the roasting, a portion of the sulphuric acid acts on the metal, dissolves it, and thus begins to form a sulphate of copper. The roasted pyrites are next exposed to the air; and when the *vitriolization* is ended, the pyritous efflorescence is lixiviated, the lixivium filtrated and evaporated, in order that it may afford a blue rhomboidal salt in crystals, called *vitriol of copper*, *blue vitriol*, *blue copperas*, or *vitriol of Cyprus*. We shall speak of it when we come to examine the combinations of this metal, under the name of sulphate of copper.

Copper, when exposed to fire, takes nearly the same colours with steel: it becomes first blue, then yellow, and at last violet. It does not melt unless when very red. When fully in fusion, it appears covered over with a green flame: it boils, and is capable of volatilization, as may be observed in the chimnies of foundries. There are also found flowers of copper in the crucibles in which it is smelted. Small filings of this metal, when

when thrown into the flames, give them a blue and green colour. It is used in artificial fire-works, on account of this property. If this melted metal be slowly cooled, and the fluid portion decanted off, that which adheres to the sides of the crucible, or roasting pot, employed in the experiment, is found in pyramidal crystals; which are larger and more regular in proportion as the fusion of the metal has been more complete, and its cooling more slowly brought on. The pyramids are quadrangular, and appear to consist of a number of octahedrons disposed one over another.

Copper heated in contact with air, burns at the surface, and changes into a blackish red oxide, as it absorbs the base of vital air. This oxide may be easily obtained by making a copper-plate red-hot, and then striking it with a hammer; the oxide comes off in scales. The same thing takes place when a copper-plate is dipped in cold water, after being made red-hot. The sudden contraction of the parts of the metal contributes to the separation of the oxide which covers its surface. The oxide falls to the bottom of the water; it is called *scales of copper*. As the copper is not completely oxidated, it may be burnt anew under the muffle of a cupelling furnace; it then takes a pretty deep brown colour; when urged with a violent heat, it melts into a blackish or brown chestnut-coloured glass. Oxide of copper may be decomposed, and deprived of its oxigene, which destroys its metallic properties, by oils, resins, &c. The scales are in part reducible by themselves; for founders buy them from coppersmiths, and use no means for their reduction but throwing them into large crucibles, above melted copper, with which, as they melt,

melt, they enter into union. The filings of this metal are melted in the same way. Oxide of copper appears to possess some saline properties; but its nature, as a salt, has not yet been the subject of examination.

Air acts upon copper; and the more easily, the more it is loaded with, and altered by moisture. It converts it into a rust, or green oxide, which appears to have some saline properties: it has a taste, and is liable to be acted upon by water: Such was the reason which induced the ancient chemists to consider copper as containing a salt. One thing remarkable with regard to this salt is, that it never penetrates deeper than the surface, and seems to contribute to the preservation of the interior parts of a mass of this metal; as may be inferred from the state of ancient medals and statues, which are well preserved under the coat of rust with which they are covered. Antiquaries call that rust *patina*, and set an high value on it; because it is a proof of the antiquity of those pieces which are covered with it. There are many artists, especially Italians, who know how to imitate this rust on copper; and thus counterfeit ancient pieces of bronze.

The oxidation of copper by humid air, appears to be owing to water in a state of extreme division. This fluid, however, does not appear to attack copper in the same manner as iron at an high temperature. It should rather seem, that cold water oxidates the metal; for it is known to be more dangerous to leave liquors to cool, than to boil them in copper vessels. When the liquor is boiling, and the vessel hot, the aqueous vapour does not attack the surface of the metal; but when the liquor

quor is cold, the drops which adhere to the sides of the vessel appear to reduce the copper to a green oxide. This oxidation may be therefore ascribed, with great probability, to the operation of the air, and the carbonic acid diffused through it; for, on distilling this rust of copper in a pneumatological apparatus, I obtained from it carbonic acid.

Copper does not combine with earthy matters. Its oxide, however, contributes to their fusion, and combines with them to form brown glasses of a lighter or a deeper shade.

Barytes, magnesia, and lime, act not in a discernible manner on copper: we know not how they act on the oxide of this metal.

Caustic fixed alkali, digested cold with filings of copper, assumes in a certain time, a very light blue shade; and the copper is covered over with a dust of the same colour. According to M. Monnet, these solutions are better effected in cold than in heat. It is, however, of importance to observe, that he made the combination with carbonate of potash, not with pure fixed alkali. Pure fixed alkali seems to have much more influence on copper: But neither of these salts does any thing more than promote and hasten the precipitation of the oxygen of the atmosphere into copper; for the oxidation never takes place without the concurrence of air.

This phenomenon is more especially remarkable, when ammoniac is brought into contact with copper; on which occasion the metal is very soon dissolved. When ammoniac is digested on filings of copper, with concurrence of air, it takes, in a few hours, a very beautiful deep blue colour; there is not, however, much of
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the copper dissolved. I have for a year observed the phenomena of this solution. I put into a small phial a portion of the caustic ammoniac with copper filings; the phial was often unstopped. At the end of some months, I found the surface of the metal covered with a blue oxide: its sides were coated with a pale blue oxide; and the under part of the phial, containing the copper, displayed, at the surface of the glass, a brown oxide, the upper part of which was yellowish. When the phial containing this liquor is closely stopped, the liquor loses its colour almost entirely; but whenever the phial is unstopped, it appears again. It does not exhibit this phenomenon in an eminent degree, except in the beginning of the operation, and when it is decanted off the copper. If the solution be not newly made, and still contain copper, it is of a beautiful blue colour, even in close vessels; however, when exposed to the air, its colour becomes still deeper. These phenomena show the influence of the oxygen of the atmosphere.

When the solution of copper by ammoniac is slowly evaporated, most part of the salt is dissipated; a portion, however, remains fixed with the oxide of the metal, and is deposited in soft crystals; as has been observed by M. Monnet. M. Sage asserts, that very beautiful crystals may be obtained from this solution by slow evaporation; and compares them to natural azure of copper. This last substance, however, affords no ammoniac when heated; is not soluble in water; and does not effloresce in the air, like that which is artificially prepared. M. Baumé says, this compound forms very brilliant crystals of a very beautiful blue colour. This so-

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lution, when exposed to the air, becomes very soon dry ; and what remains is a matter of a grass-green colour, which can be nothing but a green oxide of copper. M. Sage thinks this the origin of the malachite : but this oxide does not afford near so much carbonic acid as the malachite. An acid poured into the solution of copper by liquid ammoniac, produces scarce any precipitate, but changes the blue colour of the solution into a very light pale green. This phenomenon, which has been observed by Messrs Pott and Monnet, shows, that there is but very little oxide of copper in the ammoniac, and that it is again dissolved by the acid, or by the ammoniacal salt, formed by the addition of the acid. By adding ammoniac to the mixture, however, it may be made to resume its blue colour. Both the oxide of copper reduced to this state by fire, and all the other oxides of this metal, are instantaneously dissolved in pure ammoniac ; and the salt may be thus impregnated with a considerable portion of the metal. It takes immediately a very beautiful blue colour ; and on this account it has been proposed to use it as a test for ascertaining the presence or absence of copper in substances in which it may be suspected to exist.

Ammoniacal oxide of copper, or oxide of copper united with ammoniac, is decomposed into its two constituents, when exposed to an intense heat. The oxygen leaves the copper to unite with the hydrogen of the ammoniac, and to form water ; the copper returns to its metallic state, and the azote, the other principle of ammoniac, is disengaged in the form of gas. This experiment is one, among others, which led M. Berthollet to discover the nature of ammoniac. It appears

also, that a little nitre is likewise formed at the same time by the union of the azote of the ammoniac with a portion of the oxigene of the copper.

Though iron decomposes the solutions of copper, in fact, however, by a different attraction, namely, that of the iron for the oxigene, the sulphuric acid does not act on copper, except when concentrated and boiling : a good deal of sulphureous gas is disengaged while this solution takes place. When the solution is completed, the two substances are found to have formed a matter of the consistency of jelly, containing oxide of copper by itself, and a portion of that oxide in combination with sulphuric acid. By lixiviating this matter, and filtering the lixivium, a blue solution is obtained : when evaporated to a certain point, and suffered to cool, this solution affords oblong rhomboidal crystals of a beautiful blue colour, which are sulphate of copper. If, instead of being evaporated, this solution be left for a long time exposed to the air, it affords crystals ; but it likewise precipitates a green oxide,—the colour which all oxides of copper take that are either formed or dried in the air.

Sulphate of copper has a very strong stiptic taste ; it is even caustic. When exposed to fire, it melts very quickly : it loses its water of crystallization, and takes a bluish white colour. A very strong heat is requisite to separate the sulphuric acid, which adheres much more obstinately to oxide of copper than to oxide of iron. Sulphate of copper is decomposed by magnesia and lime : the precipitate formed by either of these substances is of a bluish white colour : when dried in the air, it becomes green ; on this account, chemists describe the precipi-

tates of sulphate of copper as green. The case is absolutely the same with those which are obtained by fixed alkalis in different states ; they are at first bluish, and take a green colour when dried : perhaps *mountain green* may be formed in this manner. It is of consequence to observe, that when sulphate of copper is precipitated by a solution of carbonate of potash, there is no effervescence excited ; a circumstance which proves that the carbonic acid unites very readily with oxide of copper. This phenomenon is not common to all solutions of metals. Ammoniac in the same manner causes sulphate of copper to yield a bluish white solution ; but the mixture soon takes a very deep blue colour ; for the ammoniac dissolves in some measure the precipitated copper ; and a very little of that salt is sufficient to dissolve again the whole of the copper separated from the sulphuric acid.

The nitric acid dissolves copper cold, and with rapidity. A good deal of very high-coloured nitrous gas is disengaged from this solution. This method Dr Priestley employed in order to obtain this gas very strong. A portion of the metal, reduced to oxide, is precipitated in a brown powder, and separated from the solution by filtration. This solution, after being filtrated, appears of a much deeper blue colour than the solution of copper by the sulphuric acid ; which shows that the copper is here more completely oxidated. This solution, carefully evaporated, crystallizes by cooling. Macquer, in his Memoir on the solubility of salts in alcohol, was one of the first chemists who observed this fact. If the crystals be very slowly formed, they become oblong parallelograms ; if deposited more quickly, hexahædral

hedral prisms, the points of which are obtuse and irregularly formed, and which appear like bundles of divergent needles. Lastly, when this solution is too quickly evaporated, it affords only a magma of no regular form. This, no doubt, is what has made chemists say, that the solution is not susceptible of crystallization. Nitrate of copper is of a very bright blue colour. It is so caustic, that it may be applied to corrode excrescences growing on the skin. It melts, according to M Sage, at a temperature of 77° degrees of Fahrenheit's thermometer. It detonizes on burning coals; but as it contains a good deal of water, the phenomenon is not very discernible. When melted in a crucible, it exhales a good deal of nitrous vapour, which may be collected by distilling it; when dried, its colour is green; when still farther urged with heat, it becomes brown; it is now nothing but pure oxide of copper. I have distilled a quantity of it in a pneumatico-chemical apparatus, and it afforded a good deal of nitrous gas, a little carbonic acid, and a little vital air: by this operation it was reduced into the state of brown oxide. Nitrate of copper attracts the moisture of the atmosphere. It may, however, be preserved for a long time in close vessels. When exposed to a hot dry air, it is covered over with a green efflorescence. It is very soluble in water, and rather more soluble in hot than in cold water. The solution, if exposed to the air in flat vessels, or hastily evaporated in dry warm weather, leaves a green oxide, such as the crystals of the salt leave on a similar occasion. Lime makes it yield a pale blue precipitate; fixed alkali, a bluish white precipitate; by ammoniac it yields flakes of the same colour, which are very quickly dissolved,

and communicate to the liquor a very bright deep blue tincture. Its precipitate by alkaline sulphures is of a brownish red colour, without a foetid smell; with the tincture of nut-gall, it gives an olive green precipitate. The sulphuric acid likewise decomposes nitrate of copper; and if it be employed in an highly concentrated state, crystals of sulphate of copper are obtained. Stahl first took notice of this decomposition; M. Monnet has since confirmed the fact related by Stahl; and I have several times had occasion to observe it. Iron has been said to have a greater affinity than copper with most of the acids. When a plate of this metal is immersed into a solution of copper in the acids, particularly in the nitric acid, the copper is precipitated in a metallic form, and colours the surface of the iron: but the iron effects this precipitation in consequence of its having a stronger affinity with oxygen than copper has. The copper again, after losing this principle, can no longer remain united with the acid, whilst the iron, after being oxidated, readily continues with it. Sulphate of copper displays the same phenomenon; and jugglers, by this process, make ignorant people believe that they can change iron into copper.

The muriatic acid dissolves copper only when concentrated and boiling; only a very little hydrogenous gas is disengaged when this solution takes place. The muriatic acid takes a very deep green, almost a brown colour. This combination forms a magma, which dissolves readily enough in water; if this magma be lixiviated, the water is of a beautiful green colour; a circumstance which serves to distinguish this from the two preceding solutions. On evaporating it slowly, and suffering

fering it to cool, it deposits prismatic crystals sufficiently regular, if the evaporation have been cautiously managed; but if the evaporation has been too quick, and the cooling too sudden, they then appear under the form of very small sharp needles. Muriate of copper is of a grass-green colour, very pleasing to behold: its taste is caustic, and very astringent; it melts by a very moderate heat, and when suffered to cool, congeals into a mass. M. Monnet affirms, that the muriatic acid adheres to it with great obstinacy, and that a very considerable heat must be applied to volatilize it: it powerfully attracts the moisture of the atmosphere; it is decomposable by the same intermedia which decompose the preceding salts of copper. I have observed, that ammoniac does not dissolve the oxide which it separates from the muriatic acid, so readily as that which it separates from the sulphuric and the nitric acids. The blue then formed is not so lively, and there remains a portion of the oxide, which the ammoniac does not thoroughly dissolve. Neither the sulphuric nor the nitric acid decomposes muriate of copper. The nitric solutions of mercury and silver decompose it, and are themselves decomposed at the instant of the mixture. A white precipitate is formed in consequence of the muriatic acid uniting with the oxide of mercury or silver; and the oxide of copper combines with the nitric acid. I have however observed, that this liquor does not assume the blue colour which a solution of copper by the acid of nitre ought to have; and that, in general, the oxide of copper formed by the muriatic acid, does not assume this colour but with great difficulty, as we have already seen with regard to ammoniac. I have

found, that in general oxides of copper pass very easily from blue to green, and with very great difficulty from green to blue. The muriatic acid dissolves oxide of copper much easier than copper itself. This has been observed by Brandt. The colour of the solution is a beautiful green; and it crystallizes as the former: a circumstance which proves, that in saline metallic combinations, the metals are always in the state of oxides, as we have already observed.

Nitre detonizes with difficulty by copper. The salt must be in fusion, and the copper very hot, in order that the deflagration may take place: still, however, it is but very weak. This operation is performed by casting copper filings on nitre in fusion in a large crucible, in order that their parts may be as much as possible in contact with each other. When the metal becomes very hot, a slight motion is observed, with faint sparklings. The residue is a brownish grey oxide, mixed with potash; it is washed; the water takes up the alkali, which still retains a little copper, and the oxide of the metal remains pure. It melts alone into a deep brown opaque glass; it is used to colour enamels. It is thought that the alkali is rendered caustic; but more experiments are necessary to ascertain this.

Copper very readily decomposes ammoniacal muriate. Bucquet, who examined this decomposition with very great care, obtained, on making the experiment in a pneumatological apparatus with mercury, from two drams of copper filings, and a dram of ammoniacal muriate,—fifty-eight inches of elastic fluid; of which twenty-six inches were very pure ammoniac, twenty-six inches detonating inflammable gas, and the remaining

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fix inches a mephitic gas, which extinguished lights, without being absorbed by water, or precipitating lime-water; and was consequently gas azote, produced by the decomposition of a part of the ammoniac. There was a little liquid ammoniac disengaged, of a fine colour, which stood immediately over the mercury. The residue was a blackish green mass, one half of which was dissolved in the water, and communicated to it a fine colour, the distinguishing characteristic of muriate of copper: the other half was a kind of brown oxide of copper, formed by the water of the ammoniacal muriate. On repeating this decomposition on four ounces of copper to two of ammoniacal muriate, with the common apparatus of a balloon, Bucquet obtained two drams and eighteen grains of blue liquid ammoniac, which gave a slight effervescence with acids, and contained about an inch of carbonic acid to the dram. He knew not how to account for the appearance of this last gas: but I suppose it might proceed from some impurities of the sal ammoniac; for on repeating the experiment with ammoniacal muriate, previously purified by sublimation, the ammoniac which I obtained was very caustic, and did not effervesce in the smallest degree with acids. Oxide of copper likewise decomposes ammoniacal muriate, and communicates to the ammoniac which it disengages a portion of carbonic acid, that renders it effervescent. This alkali is always blue, because it takes off with it a small portion of oxide of copper, which colours it. Acids, however, do not precipitate an atom of the metal. There are two medicines prepared in pharmacy with ammoniacal muriate and copper; the former of which has received the name of *cup-*

to rust than pure copper, but at the same less ductile. The more this metal resembles gold, the brittler it is: besides, its nature varies according to the proportion in which the two substances are mixed together, and the precautions taken in melting them; its varieties are similar, pinchbeck, Prince Rupert's metal, and Manheim gold. 2 By cementing plates of copper with native oxide of zinc, or lapis calaminaris reduced to powder and mixed with coal, and making the crucible in which they are contained red-hot; the copper then forms *yellow brass*. This last compound is not so liable to rust as copper: it is equally malleable, and more fusible; but if exposed for ever so short a time to a strong heat, it loses its zinc, and becomes red copper again.

Copper combines with mercury, but not readily; yet by trituration very thin leaves of copper with mercury, these metals may be formed into a sort of amalgam. A plate of this metal, immersed into a solution of mercury by an acid, takes a fine silver colour, owing to the mercury being reduced and precipitated by the copper, which has a greater affinity than mercury with oxygen.

Copper and lead combine very well by fusion; as appears by the formation of the loaves of eliquation.

It is combined with tin in two ways; either by pouring melted tin on the surface of a plate of copper, or by melting the two metals together. The former operation is used in tinning copper; the latter forms bronze. Copper vessels to be tinned, are first well scoured, to render the surface on which the tin is to be applied

plied smooth and bright. They are next rubbed with ammoniacal muriate, to make them perfectly clear. They are then made hot, and powdered rosin is cast upon them. This substance covers the surface of the copper so as to prevent it from being oxidated. At last the melted tin is poured on, and spread over it. Complaints have been made, and with good reason, that the tinning of copper vessels is not sufficient to defend them from the action of air, of moisture, and of salts; because such vessels are often observed to be covered with verdigris. This might be effectually remedied by laying on a thicker coat of tin, were there not reason to fear that when such vessels are exposed to any degree of heat above that of boiling water, the tin is then liable to be melted, and thus to expose the surface of the copper uncovered. To prevent such an accident, the tin may be alloyed with iron, silver, or platina, to render it harder and less fusible, in order that it may be laid in thicker layers on the copper. Mixtures of this kind are already made use of in several manufactories. It is amazing how small a quantity of tin is sufficient to tin copper; for Messrs Bayen and Charlard have ascertained, that a pan nine inches in diameter, and three lines in depth, gained only an additional weight of one and twenty grains by being tinned. This trifling quantity, however, is sufficient to prevent the danger which might otherwise arise from the use of copper vessels, when care is taken not to suffer substances capable of dissolving tin to remain too long in such vessels, and especially to renew the tinning frequently, as friction, heat, and the action of the spoons used in stirring substances boiled in them, very soon destroy the tinning.

ning. There is one thing, however, respecting the tin used by coppersmiths for tinning pans, which we cannot be too much on our guard against. It is often alloyed with one fourth-part of lead ; the bad effects of which are to be feared, as lead is well known to be very soluble in fats and acids. Government should therefore take measures to prevent coppersmiths from being cheated when they purchase their tin, and from employing the tin of Malacca or Banca, in any other state but as it comes from the East Indies, before being melted again, and having its purity debased by our tin-workers.

M. de la Folie, a citizen of Rouen, who merits the respect of the public for those chemical researches which he has prosecuted on matters relative to the arts, and for the useful discoveries with which he has enriched dyeing, pottery, and many other of the manufactures carried on at Rouen ; has proposed, in order that the inconveniences and dangers attending the use of tinned copper may be avoided, to employ, in its stead, iron plated with zinc ; which, as we have already seen, is productive of no dangerous effects. Many people have already adopted the use of such vessels with advantage ; and it is to be wished, that they were in general use.

Tin melted with copper gives a metal, the specific gravity of which is greater than that of either of the two metals of which it is made up, in consequence of their mutually penetrating each other in a very intimate manner. The greater the proportion of tin in this mixture, so much the more white, brittle, and sonorous, is the mixture. When very white, it is called *bell-metal*:
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when it contains more than an equal proportion of copper, it is yellow, and bears the name of *bronze*, or *brass*. It is moulded into statues and into cannons, which must be so solid as not to burst by a moderate force ; and at the same time not so ductile as to lose their form by the impulse of bullets.

Copper and iron may be united by fusion or by soldering. This combination, however, does not very easily succeed. When a mixture of these two metals is melted in a crucible, the iron is found to be often intermixed, but not perfectly united with the copper. Copper decomposes the mother-water of sulphate of iron ; and yet iron has a greater affinity than acids with copper.

The uses to which copper is applied are very various, and very well known. A great variety of utensils are made out of it. Yellow copper, or an alloy of copper with zinc, is principally employed for such purposes, on account of its superior ductility and beauty. Copper being a very violent poison, should never be administered as a medicine. The remedies most usually applied in the case of poisoning by copper reduced to oxide or verdigris, are emetics, water drunk in large quantities, alkaline sulphures, alkalis, &c.

Sulphate of copper contains in the hundred weight 30 *lib.* of acid, 43 *ib.* of water, and 27 *lib.* of copper.

M. Chaptal obtained from a solution of copper in the nitric acid, by slow spontaneous evaporation, *white* rhomboidal crystals, which decrepitated upon the coals, emitted by heat, a red gas, and left a grey oxide. H.

C H A P. XX.

Of Silver.

SILVER, called *Luna*, or *Diana*, by the alchemists, is a metal of a white colour, and the most lively brilliancy. It has neither taste nor smell. Its specific gravity is such, that it loses in the hydrostatic balance about one-eleventh part of its weight. A cubic foot of this metal weighs seven hundred and twenty pounds. So great is the ductility of silver, that it may be reduced to leaves as thin as paper, and to threads finer than hairs. A grain of silver may be extended so as to contain an ounce of water. Its tenacity is so considerable, that a wire of silver, one tenth of an inch in diameter, is sufficient to support the weight of two hundred and seventy pounds without breaking. It possesses hardness and elasticity in an inferior degree to that in which copper possesses these qualities; it is, next after copper, the most sonorous of all metals. It becomes hard under the hammer, but may be easily deprived by heating of the hardness which it thus acquires.

Messrs Tillet and Mongez have crystallized silver. They obtained it in quadrilateral pyramids, sometimes solitary on the edges of the crucible, at other times laterally united in groups.

Silver is found in various states in nature. The following are the silver ores most strikingly distinguished from each other.

1. Native or virgin silver. It is known by its lustre and ductility. It appears under an amazing variety of forms. It is frequently in irregular masses, the size of which is more or less considerable. It is sometimes in capillary threads twisted round; its formation then appears to be owing to the decomposition of a red silver ore, as has been observed by Henckel and M. Romé de Lillé. It is likewise found in plates, or in pieces of network resembling spiders webs, which the Spaniards on this account call *arané*; sometimes again in a vegetable form, or in branches consisting of octohædrons rising one over another. Some of these specimens resemble the fern-leaf, others are separate cubes and octohædrons, with truncated angles; but these last are rare. Native silver is often dispersed in a quartzose gangue; it is sometimes found in fat earths. It is found in Peru, in Mexico, at Kongsberg in Norway, at Johan Georgenstadt and Ehrenfriedersdorf in Saxony, at St Marie, at Allemont in Dauphiny, &c. This metal is not known to exist in nature in the state of oxide.

2. Native silver, in union with gold, copper, iron, antimony, or with gold and copper together, or with arsenic and iron together. These various native combinations of silver are found at Freyberg in Saxony,

and in the mines of Guadal-Canal in Spain. But it is to be observed, that the proportion of the extraneous substances is very trifling.

3. *Vitreous silver ore* consists, according to most mineralogists, of silver and sulphur. It is of a blackish grey colour like lead; it is also brown, greenish, yellowish, &c. and it may be cut with the knife as well as that metal. It is frequently irregularly shaped, sometimes in octohædral crystals, the angles of which are truncated. M. Monnet takes notice of a variety, which, instead of being divisible by the knife, falls into powder. This ore affords from seventy-two to eighty-four pounds of silver in the hundred weight. It melts very easily: when exposed to a heat so moderate as not to melt it, the sulphur is dissipated, and leaves the virgin silver in a vegetative form, or in filaments.

4. *Red silver ore* is often of a deep colour, sometimes transparent, and crystallized in cubes, with their edges truncated, or in hexahædral prisms, terminating in trihædral pyramids: at Potosi this is called *roffi-clera*. The silver is combined in it with sulphur and arsenic. When it is broken, its colour is lighter within, and it appears to consist of small needles or prisms, converging like stalactites. If exposed, with proper management, to a fire strong enough to make it red-hot, the silver is reduced, and takes a capillary vegetative form, like native silver. It affords from fifty-eight to sixty-two pounds of silver in the hundred weight. This species is diversified into varieties, by the properties of colour, form, and gravity, &c. It is generally found in all such places as contain the other silver ores.

5. *Silver*

5. Silver with arsenic, cobalt, and iron mineralized by sulphur. Bergman says, that in this ore the silver is sometimes above the proportion of $\frac{1}{100}$. This ore is sometimes grey and sparkling, sometimes of a dark and dusky appearance; efflorescences of cobalt are observable upon it. The silver ore called *goose-dung* belongs to this species.

6. The grey silver ore, which differs from the copper ore called *Fahlertz* only in containing a larger proportion of this precious metal. It is either in masses or in triangular crystals, with their sides cut sloping. The largest of these crystals are not of a very bright colour; the small, being dispersed over a smooth gangue, are of so lively a lustre as to afford a very pleasing spectacle when light falls upon them. Grey silver affords from two to five marks of silver in the hundred weight. Grey silver is sometimes introduced into organic matters, and moulded into an exact imitation of their form. It is then called *figured silver ore*. Of this kind is that resembling blades of corn, and that which M. Romé de Lille has observed in the form of the cones and scales of the pine-tree. This ore contains silver, copper, iron, arsenic, and sulphur. When the proportion of the iron is very small, it is then called *white silver ore*. This latter ore is not to be confounded with galena containing silver, which is sometimes called by the workmen *silver ore*.

7. Black silver ore, called by the Spaniards *nigrillo*, is, according to Messrs Lehman and Romé de Lille, nothing but red or grey silver ore decomposed, and brought into a kind of middle state between its original state and that of native silver: it is sometimes found to con-

tain native silver. The latter of these two mineralogists has observed, that when solid, spongy, or worm-eaten, it may be considered as produced from the red and vitreous ores, and is then richer than when friable and pitch-coloured; when it may be considered as originating from the alteration of grey or white silver ores. It therefore affords various products. In general, it affords from six or seven to nearly sixty pounds of silver in the hundred weight.

8. *Corneous silver ore*, or the natural combination of silver with muriatic acid, and a little sulphuric acid, is a pearl-grey, a violet-grey, or a yellowish grey; sometimes, though but seldom, it is semi-transparent; it is soft, and may be easily crushed or cut: it melts at the flame of a taper. It is found in cubic crystals, but oftenest in irregular masses. It frequently contains lumps of native silver. It was formerly thought to contain sulphur and arsenic; but mineralogists have now agreed in respect to its nature. Messrs Cronstedt, Lehman, and Sage, Woulfe, Lommer, and Bergman, have found it to contain muriatic acid, which is disengaged by heat. Woulfe has besides ascertained, that it contains sulphuric acid. It is found at Saxony, at St Marie, at Guadal-Canal in Spain, and at Allemont in Dauphiny.

9. *The soft silver ore* of Wallerius, is silver either native or mineralized, and intermixed with more or less coloured earth. Earths containing silver vary in colour from a dirty grey to a deep brown.

10. Lastly, Silver is often found in combination with other metallic matters in ores, the history of which we have already given. Such are mispickel, the grey cobalt

balt ore, kupfernickel, or nickel ore, sulphure of antimony, which often affords the variety called *silver ore* in *feathers*, *blende*, *galena*, *martial pyrites*, and *white copper ores*: the latter are only grey silver ores. All of these substances, many times, contain so much silver as renders the working them for the sake of this precious metal profitable. But it is easy to see, that they cannot, with any propriety, be described as peculiar silver ores; and deserve only to be mentioned as containing silver.

Silver ores are assayed in various ways, according to the nature of the ore. All that is strictly requisite in assaying such as contain native silver, is to pound and wash them. In order to separate the metal entirely from extraneous substances altering it; after being washed, it may be triturated with running mercury. The mercury dissolves the silver, and being then volatilized by fire, leaves the perfect metal separate. Sulphureous silver ores need to be roasted, and afterwards melted with a greater or a less quantity of flux. The silver obtained by this melting is commonly alloyed with lead, copper, iron, &c. To separate it, and to ascertain exactly what quantity of the precious metal this mixture contains, a process entirely chemical, and founded on the consideration of the properties of the imperfect metals, is employed. As lead is susceptible of vitrification, and acts in the quality of a flux on the imperfect metals, such as iron and copper, but is incapable of affecting silver in the same manner; lead is therefore employed to separate the perfect metal from such imperfect metals as alter it. The greater the proportion of the extraneous matters by which the silver is alter-

ed, so much the more lead must be made use of to separate them. This alloy is put into flat porous vessels, made of calcined bones and water. These roasting pots, which are called *cupels*, as being in the form of small cups, are proper for absorbing the lead-glass formed in this operation. The silver after this remains pure. In order to determine what quantity of the imperfect metals any mass of silver contains, it is considered as consisting of twelve parts, which are called *penny-weights*; and each of these consists of twenty-four grains. If the mass of silver under examination has lost in the cupels only the twelfth part of its weight, it is called *silver of eleven penny-weights*: if it has lost but a twenty-fourth part of its weight, it is *silver eleven penny-weights and twelve grains fine*, and so on. The cupel is found, after this operation, to have acquired a considerable addition of weight; it contains vitreous oxide of lead, and of the other imperfect metals, which were in combination with the silver, and have been separated by the lead. As the lead almost always contains a little silver, it must be at first cupelled by itself, in order to ascertain what quantity of silver it contains; from the button of fine silver obtained, a deduction must be made for the small portion known to be contained in the lead which is employed, and is called a *witness*. The cupellation exhibits a phenomenon from which the artist understands the state of his operation. As the silver becomes pure by vitrification, and the separation of the lead, it assumes a much more brilliant appearance than that with which the lead is still intermixed. The lustre by degrees increases; and when the whole surface of the metal becomes pure and

of a dazzling brightness,—at the very instant when the whole assumes such an appearance. the operation is finished. The silver, after being thus cupelled, is entirely purified from the imperfect metals which it before contained: but it may still contain gold; and a new process must be employed to separate the two perfect metals. As gold is much less liable than silver to be altered by a great many menstrua, the silver is dissolved by the nitric or the muriatic acid, and by sulphur; and the gold, which is scarce liable to be affected by these solvents, remains pure. This way of separating silver from gold is called *parting*. We will speak of the various ways of parting these metals, after describing in what manner the several solvents which are used for this purpose act upon the silver, and when we treat of the alloy of silver with gold.

The processes, in the great way, for extracting silver from its ores, and obtaining it pure, are nearly the same with those which we have described as proper for assaying the ores of this metal. There are, in general, three modes of treating silver in the great way. The first consists in triturating virgin silver with mercury: this amalgam is washed, to purify it entirely from earth: it is then strained through goat-skin, and distilled in an iron retort; after which, the silver is melted, and run into ingots. This process cannot be applied to silver ores containing sulphur. These must be roasted and mixed with lead, in order to refine the precious metal by cupellation. This is the process to which rich silver ores are subjected. As to such as are poor, the method employed upon them is different from either of these two. They are melted without being previously roasted,

with a certain quantity of pyrites. This is called *crude fusion*, and affords a mat of copper containing silver, which is treated with lead by eliquation. The lead which takes up the silver as it melts, is afterwards scorified in the cupel, and then leaves the perfect metal pure. Cupellation in the great way differs from that which is performed in the small way; for, whereas in the former the scorified lead is blown over the edges of the cupel with bellows, in the assay the vitrified oxide of lead is absorbed by the cupel.

The silver obtained by the processes which we have described, is, in general, much less liable to alteration than any of the other metals of which we have as yet given the history. The contact of light, however long the metal remain exposed to it, produces no change of its properties. Heat melts it, makes it boil, and volatilizes it, but without altering its nature. A heat sufficient to make it become first red, and afterwards white, is requisite to melt it: it is more fusible than copper. After being kept for some time in fusion, it swells, and exhales vapours, which are nothing but silver volatilized. What puts this fact beyond doubt is, that portions of the metal are found in the funnels of chimnies in which it is melted in large quantities. It is confirmed by a fine experiment of the Academicians of Paris; they exposed very pure silver to the focus of M. de Trudaine's lens, and observed the melted metal to diffuse a thick smoke, which being intercepted by a plate of gold, was fixed upon it, and whitened its surface.

Silver, when slowly cooled, is susceptible of a regular form, and crystallizes in quadrangular pyramids.

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M. Baumé observed, that this metal takes, as it cools, a regular form ; which appears from its surface being covered over with filaments resembling the threads of a feather. I have remarked, that the button of fine silver obtained by cupellation, often exhibits on its surface small spaces with five or six sides, arranged like the flags of a pavement. But its crystallization in tetrahedral pyramids has not been carefully examined by any but Messrs Tillet and the Abbé Mongez.

It was long imagined, and many chemists are still of opinion, that silver is secure against the joint action of heat and air: It is certain that this metal suffers no apparent alteration when held for some time in fusion, and in contact with air: Juncker, however, related, that on treating silver for a considerable time by reverberation, in the way of Isaac of Holland, he found it to change into a vitreous oxide. This fact has been confirmed by Macquer. He exposed silver twenty times successively in a porcelain crucible, to the heat of the porcelain furnace at Seves, and obtained, by the twentieth fusion, a vitreous matter, of an olive-green colour, which he considered as a true vitreous oxide of silver. When this metal is heated in the focus of a burning-glass, its surface is always covered with a white pulverulent matter, and a greenish incrustation is formed on the body on which it rests. These facts remove every doubt that could be reasonably entertained of the alteration of silver in such circumstances. Though much more refractory against all attempts to reduce it to an oxide than any other metal, yet is it liable to be at length changed into a white oxide, which, when treated

in a very strong fire, takes an olive-green colour. It might perhaps be possible to obtain an oxide of silver, by reducing the metal to very thin plates or leaves, and heating it for a considerable time in a matrafs, in the same way as is done with mercury. The electric spark appears likewise to oxidate silver. It is certain, at least, that this metal has but a very faint tendency to combine with the base of vital air, and that heat does not contribute to this combination so much as in the case of any of the other metals; but, on the other hand, destroys it by a very slight effort; for all the oxides of silver may be easily reduced without addition; and oxigene must therefore be but very imperfectly combined with the metal, since it can be detached from it so as to form vital air, by the action of light and heat alone.

Silver is liable to no alteration from air; its surface, in a long space of time, is a very little sullied by the action of the atmosphere. Water acts not upon it; earthly matters do not combine with this metal: Its oxide, if melted with glasses, would probably communicate to them an olive-green colour.

Neither the alkalis nor the salino-terrene substances act in a sensible degree on silver. The sulphuric acid, when highly concentrated and boiling, and when the metal is presented in a state of extreme division, dissolves it. A considerable quantity of sulphureous acid gas is disengaged from this solution; and the silver is reduced to a white matter, on which a new quantity of sulphuric acid must be poured, in order to dissolve it. By evaporating this liquor, sulphate of silver is obtained in small needles. I have several times obtained this
salt

salt in plates, formed by the longitudinal junction of a number of these needles. This salt melts when exposed to fire, and is of a very fixed nature. It is decomposable by alkalis, iron, copper, zinc, mercury, &c. All the precipitates obtained by alkalis may be reduced, without addition, to fine silver, in close vessels.

The nitric acid oxidates and dissolves silver rapidly, even without the help of heat. This solution even takes place at times so quickly, that to prevent the inconveniences arising from this circumstance, it is found expedient to have the silver in lumps when exposed to the acid. A considerable quantity of nitrous gas is disengaged on the occasion, and a white precipitate is produced, more or less in quantity, if the acid of nitre have been mixed with any portion of sulphuric or muriatic acid. The nitric acid usually gives it a blue or a green colour. If the silver be pure, it loses that colour, and becomes transparent as soon as the solution is fully accomplished: but if the silver happen to contain copper, the solution retains a lighter or deeper greenish shade. The purest silver that can be obtained often contains gold. In this case, as the nitric acid is scarce capable of acting on that metal, when it acts on the silver it separates small blackish flakes, which fall to the bottom of the vessel, and prove to be gold. It is in consequence of the nitric acid acting in so different a manner on these two metals, that it is happily employed to separate them in the operation of parting by aquafortis. The nitric acid dissolves a quantity of silver equal to half its own weight. This solution is exceedingly caustic; so much so, that it produces black spots on the epidermis, and eats entirely through it. When fully estimated,

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it deposites thin bright crystals, like the boracic acid : when half the quantity is evaporated, it affords, by cooling, flat crystals, which are either hexagonal, or triangular, or square, and appear to consist of a great many small needles joined laterally. These flat crystals are obliquely arranged one over another. They are transparent and very caustic. They are called *Lunar crystals* : their proper name is nitrate of silver. This salt is speedily altered by the contact of light, and rendered black by combustible vapours. When placed on a burning coal, it readily detonizes, leaving after the detonation a white powder, which consists of pure silver : it is very fusible. If exposed to fire in a crucible, it swells at first as it loses the water of its crystallization ; and after that, remains in fusion without motion. If suffered to cool in this state, it becomes a grey mass, slightly needled ; a preparation which is known in surgery under the name of *Lapis infernalis*. But there is no occasion to make use of crystallized nitrate of silver when we wish to obtain this medicine ; the process by which it is made up is too tedious, and too expensive. It is sufficient to evaporate to dryness a solution of silver by the nitric acid, to put the residue in a silver crucible or ladle, as M. Baumé advises, and to heat it slowly till it melt : it may be then run into a mould, to give it the form of small cylinders. When these cylinders are broken, they appear to consist of needles diverging in radii from the centre of the cylinder, and terminating at its circumference. In composing the *infernal stone* of nitrate of silver, we must beware of heating it too long ; otherwise a part of the salt will be decomposed, and formed into a button at the bottom of the

the crucible. In order to have an opportunity of observing what passes in this operation, I distilled this salt in a pneumato-chemical apparatus; I obtained nitrous gas and vital air, mixed with azotic gas. In my materials I found the silver entirely reduced; the glass was become opaque, like enamel, and was of a beautiful chestnut-brown colour. The brown colour which the glass takes on this occasion must, no doubt, be owing to oxide of manganese, or some other substance contained in it; for the colour of glass formed of oxide of silver is nearly an olive green, as we have already observed.

Nitrate of silver does not attract moisture when exposed to the air; it dissolves very readily in water; and may be crystallized from the solution by a slow evaporation of the fluid.

The nitric solution of silver is decomposed by salinoterrine substances and alkalis; but the phenomena vary greatly, according to the state of these matters. Lime-water produces a very copious olive-coloured precipitate. Fixed alkali, saturated with carbonic acid, makes it yield a white precipitate: caustic ammoniac causes it to afford a grey precipitate, inclining to olive-green. This precipitation does not take place till a considerable time after the two substances have been mixed.

Although the nitric acid acts with a stronger energy on silver than any of the other acids, there are, however, others which have a greater affinity with its oxide, and adhere to it with more obstinacy: the sulphuric and the muriatic acids detach the oxide from the nitric acid. For this reason, when a few drops of either of these acids are poured

poured into a nitric solution of silver, a precipitate is produced ; which, when the sulphuric acid is employed, is a white powder ; and when it owes its origin to the muriatic acid, is in thick flakes like a *coagulum*. In the former case, the precipitate is sulphate of silver ; in the latter, muriate of silver. As neither of these two salts is very liable to solution, they therefore subside in a precipitate. It is not necessary that the acids be in a state of liberty when applied to this purpose ; the neutral salts, which are formed by their combinations with alkalis and salino-terrene substances, serve the purpose equally well. A double decomposition and a double combination then take place ; for the nitric acid, separated from the silver, enters into combination with the base of the sulphuric or muriatic salt.

On this difference among the acids, in respect to the manner in which they act upon silver, there is founded a process which is employed to procure the nitric acid in an high state of purity, and unmixed with any other acid : in a word, in that state in which it is requisite to have it for many operations in metallurgy, and for most chemical experiments. Distilled spirit of nitre is generally mixed with a certain quantity of sulphuric or muriatic acid ; and chemists have therefore industriously sought to separate these extraneous fluids, and have found no happier expedient than the use of the nitric solution of silver. This solution is poured into the impure nitric acid till it cease to produce a precipitate ; the sediment of sulphate or muriate of silver is suffered to settle ; the acid is decanted off, and distilled by a moderate heat, to separate from it that small quantity of salts of silver which may still be contained in it. The product

duct of this distillation is very pure nitric acid : in the arts it is called *precipitated aquafortis*.

Most metallic matters are capable of decomposing the nitric solution of silver, as they have in general a greater affinity than that metal with oxygen. Arseniate of potash, dissolved in water, produces in the nitric solution a reddish precipitate, which originates from the union of the silver with the arsenic acid. This precipitate resembles red silver ore. The silver may be obtained in its metallic state, as a precipitate from this solution, by most of the metals and the semi-metals. But the separation of this perfect metal by mercury and copper is particularly worthy of our notice, on account of the phenomena which attend the first of these metallic substances, as it acts on silver, and the useful purposes which are served by bringing the second to act upon it.

Silver, when separated from the nitric acid by mercury, is in a metallic state; and the precipitate subsiding slowly, produces, as it subsides, a regular figure, known by the name of *Diana's tree*, or *the philosophic tree*.— This species of crystallization may be obtained by several different processes. Lemery directed to take an ounce of fine silver, to dissolve it in nitric acid moderately strong, and to dilute the solution with about twenty ounces of distilled water, adding two ounces of mercury. In the space of forty days a very beautiful vegetative form is produced. Homberg gives another process, much shorter than this. His process is, to make a cold amalgam of four drachms of silver in leaves, with two drachms of mercury : this amalgam is to be dissolved in a sufficient quantity of nitric acid, and a pound and an half of distilled water to be added to the solution : into
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an ounce of this liquor put a small ball of a soft amalgam of silver, and the precipitation of silver will immediately take place. The silver being precipitated and combined with a part of the mercury, is deposited in a kind of prismatic filaments on the surface of the amalgam. Other filaments rise above the first, so as to present a kind of vegetation in the form of a bush. Lastly, M. Baumé has described a way of obtaining a tree of Diana, a little different from Homberg's process, and more infallibly attended with success. He directs to mix six drachms of the solution of silver, and four drachms of a solution of mercury, by the nitric acid, both fully saturated; to add to the mixture five ounces of distilled water; and then to pour it into an earthen vessel, upon six drachms of amalgam, made up of seven parts of mercury, with one of silver. Either of these processes succeeds in a much shorter time than Lemery's, in consequence of the relation subsisting between the metallic matters and their mutual action. In fact, the mercury contained in the solution attracts the mercury of the amalgam; the silver of the amalgam acts in the same way on the silver of the solution: and of consequence the silver is more speedily precipitated. The mercury of the amalgam, being more than is requisite to precipitate the silver of the solution, produces a third effect, which we must not suffer to escape unnoticed: It attracts the silver by its affinity and tendency to combine with that metal: a combination is actually effected between them; for the vegetation of the tree of Diana is a real amalgam, brittle and crystallized. This crystallization succeeds much better in conical vessels, such as glasses, than in round or wide vessels, like the cucurbite
recommended

commended by M. Baumé. It is almost unnecessary to mention, that the vessel must not be moved, nor exposed to any impulse which might hinder the regular symmetrical arrangement of the amalgam.

Copper immersed into a solution of silver likewise precipitates it in a bright metallic form. This is the process usually employed to separate silver from its solvent, after the operation of parting. Plates of copper are dipped into the solution, or rather the solution is put into a copper vessel; the silver is immediately separated in whitish grey flakes. When the liquor becomes blue, and ceases to precipitate silver, it is decanted off. The silver precipitated is repeatedly washed, then melted in crucibles, and passed with lead into a cupel, to separate from it a portion of copper, which became united with it in the precipitation. The silver which passes through this operation is purer than any other kind: it is no less than twelve penny-weights fine. From these two cases of the precipitation of silver by mercury and by copper, it appears that metals separated from their solvents by metallic matters, are precipitated with all their properties. This phenomenon, as we have shown in the history of copper, takes place in consequence of the metals immersed into the solution of silver, robbing it of its oxygen, with which they have a greater affinity.

The muriatic acid does not dissolve silver immediately; but it dissolves its oxide readily enough. This acid, supersaturated with oxygen, easily oxidates the metal. Such, no doubt, is the reason of what happens in the *concentrated parting*. This operation consists in exposing to fire, plates of gold alloyed with silver, cemented with

a mixture of sulphate of iron and muriate of soda : The sulphuric acid, disengaging the muriatic, communicates to it a portion of its own oxigene ; and the muriatic acid then acts upon the silver, and dissolves it.

There is a much easier and more expeditious process for combining the muriatic acid with oxide of silver. The acid is poured into a nitric solution of the metal : a very copious precipitate is instantaneously formed, and proves to be a combination of the muriatic acid with silver ; for the metal has a greater affinity with the muriatic than with the nitric acid, and of consequence forsakes the latter to combine with the former. The same combination may be obtained by pouring muriatic acid into a solution of sulphate of silver ; for this acid has likewise a greater affinity than the sulphuric with the metal. The muriatic acid may also be combined with silver, by heating the acid with oxide of the metal precipitated from the nitric acid by fixed alkali.

Muriate of silver possesses various properties worthy of notice. It is remarkably fusible. When exposed in a phial to a moderate heat, such as that of hot ashes, it melts into a grey semi-transparent substance, bearing no small resemblance to horn ; and for this reason called *luna cornea*. If run upon a surface of porphyry, it fixes into a friable matter, appearing to be crystallized in fine silver needles. When long heated in contact with air, it is decomposed ; it passes easily through the crucibles ; one part of it is volatilized, and another reduced to metal ; so that it now takes the form of silver globules dispersed through muriate of silver ; a portion of the salt remaining not decomposed. This salt, when
exposed

exposed to light, loses its whiteness, and becomes speedily brown. It dissolves in water; but, according to an experiment of M. Monnet's, a pound of distilled water dissolves only three or four grains. Alkalis are capable of decomposing muriate of silver, when it is either dissolved in water, or exposed to fire, together with any of these salts. This is one way of obtaining the finest and purest silver possible. Mix, for this purpose, four parts of potash, or carbonate of potash, with one of muriate of silver: Put the mixture into a crucible, and melt it; when it is completely melted, take it out of the fire; suffer it to cool, and then break it: separate the silver; which is found under the muriate of potash formed during this operation, and the excess of alkali. M. Baumé, to whom we owe this process, asserts, that the quantity of alkali which he directs to be employed, hinders the muriate of silver from passing through the crucible, by acting on all its parts, and decomposing them at once. Margraff has given another process for reducing this salt, and obtaining from it silver perfectly pure. Triturate in a mortar five drachms and sixteen grains of muriate of silver, with an ounce and an half of ammoniacal carbonate, and as much distilled water as may be sufficient for making it into a paste: stir this mixture till the swelling and effervescence which at first take place in it cease: then add three ounces of pure mercury, and triturate the whole till it be formed into a beautiful amalgam of silver: wash it with a good quantity of water; continue the trituration, and repeat the washing till the water run off very clear, and the amalgam become very bright: then dry the amalgam, and distil it in a retort till the vessel take a white red colour: the

mercury now passes into the receiver, and the silver is found in an high state of purity at the bottom of the retort. In this manner the metal may be obtained of the highest purity possible, and without any sensible loss. This sort of silver should be used in nice chemical experiments. The water employed to wash this mixture carries off two substances; a certain quantity of ammoniacal muriate, which it holds in solution, and a white powder not soluble in water. When the white powder is sublimated, there is a small quantity of silver found at the bottom of the sublimatory vessel. This experiment proves, that muriate of silver cannot be completely decomposed otherwise than by double affinity. In fact, in Margraff's process, the cause of the ammoniac combining with the muriatic acid is, that the silver is first detached from the acid by the mercury, and the alkali then becomes capable of effecting an event which it could not otherwise have produced. But this tedious and expensive operation can only be employed in the small way, and in the laboratory. To reduce a great quantity of muriate of silver at once, either fixed alkali, or some metallic substance having a greater affinity than silver with the muriatic acid, must be employed. Such, among others, are antimony, lead, tin, iron, &c. One part of muriate of silver melted in a crucible, with three parts of any of these matters, affords, at the bottom of the crucible, the silver reduced and separate; while the metal employed to produce the separation appears in union with the muriatic acid. The silver precipitated in this manner is very impure; it always contains more or less of the metal employed to separate it; and as, in compliance with the advice of Kunckel, lead

is most commonly employed for the purpose, this silver needs to be cupelled; nor can it even be rendered equally pure with that which is reduced by alkalis, or by Margraff's process.

The nitro-muriatic acid acts with considerable force on silver; and, as it dissolves it, causes it to precipitate. The manner in which this effect takes place may be easily understood: the nitric acid dissolves the metal at the first, and the muriatic acid, detaching itself from the nitric, forms a neutral salt with the silver; which, having no great tendency to solution, is deposited in sediment. This process may be used to separate silver from gold.

We know but little about the manner in which the other acids act upon silver; only, a solution of borax produces in the nitric solution of this metal a very copious white precipitate; which precipitate consists of boracic acid in union with oxide of silver.

This metal does not appear liable to be altered by neutral salts. It is certain, at least, that it does not detonize with nitre, nor decompose ammoniacal muriate. Silver, in consequence of its being unalterable by nitre, may be easily separated from imperfect metals, such as copper, lead, &c. by detonizing them with that salt. This metal, alloyed above the just proportion with some of the baser metals, is melted with nitre: the salt detonizing burns the imperfect metal; and the silver falls to the bottom of the crucible in a state of much higher purity.

Almost all combustible matters act with more or less force on silver. No metal is sooner tarnished or coloured by inflammable matters. Sulphurated hydrogenous

gas, from whatever substance disengaged, communicates to silver, the instant it comes into contact with it, a blue or violet colour, inclining to black, and considerably diminishes its ductility. It is known that foetid animal vapours, such as proceed from houses of office, from putrefied urine, and from hot eggs, produce the same effect on this metal. The mutual action of these bodies, and the combination which takes place on the occasion, have not yet been examined.

Sulphur combines very readily with silver. This combination is usually effected by stratifying on a crucible plates of the metal with flowers of sulphur, and melting the mixture hastily: the result is a violet black mass, much more fusible than silver, brittle, and needled; in a word, a true artificial ore. This composition is easily decomposed by the action of fire, on account of the volatility of sulphur, and the fixity of silver: the sulphur is consumed and dissipated, leaving the silver pure. Alkaline sulphure dissolves this metal in the dry way: on melting one part of silver with three of sulphure of potash, the metal disappears, and may be dissolved in water together with the sulphure. An acid poured into the solution produces a black precipitate of sulphurated silver. Leaves of silver put into a solution of sulphure of potash speedily take a black colour; and it appears that the sulphure forsakes the alkali, to unite with the metal and mineralize it; as we have already observed of mercury.

Arsenic combines with silver, and renders it brittle. We know not yet how the acid of arsenic affects this metal.

It combines, but not without great difficulty, with cobalt.

It enters readily enough into an alloy with bismuth, forming with it a brittle mixed metal, the specific gravity of which is greater than that of either of the two metals taken separately. According to Cronstedt, silver does not unite with nickel. These metals, when melted together, are disposed separately, one beside the other, as if their specific gravities were precisely equal.

It melts with antimony into a very brittle alloy. It appears to be capable of decomposing sulphure of antimony, by combining with the sulphur of that mineral, with which it has a greater affinity than antimony has.

Silver easily combines with zinc by fusion. From this combination there results an alloy granulated at the surface, and very brittle.

In mercury, even cold, it is completely dissolved. All that is necessary to effect this solution, is to malaxate leaves of silver with this metallic fluid: an amalgam is by this means instantaneously produced; the consistency of which varies with the respective quantities of the two substances. This amalgam may be brought into a regular form by fusion and slow evaporation: it affords tetrahedral prismatic crystals, terminating in pyramids of the same form. The mercury becomes in some degree fixed in this combination: for, to separate it from the silver, a stronger heat is required than what is sufficient to volatilize it when taken by itself. Silver decomposes corrosive mercurial muriate, either in the dry or in the humid way.

It unites perfectly with tin: but entirely loses its duc-

tility when alloyed with ever so small a proportion of that metal.

It enters readily into union with lead, which renders it very fusible, and destroys its elasticity and sonorousness.

It forms an alloy with iron, which might perhaps be very advantageously employed in the arts.

Lastly, It melts and combines in any proportion with copper. Copper does not destroy its ductility; but renders it harder and more sonorous; and the alloy is often employed in the arts.

Silver, on account of its ductility, and its being proof against the attacks of fire and air, is a metal singularly useful. Its lustre recommends it for an ornament: it is laid on the surfaces of various bodies, and even of copper: it is wrought into stuffs, and adds considerably to their beauty. But the most important use for which it serves, is that of a good material out of which vessels of all kinds may be made; and its hardness and ductility render it peculiarly suitable for this purpose. The silver wrought into plate is commonly alloyed with $\frac{1}{4}$ of copper, which improves its hardness and cohesion, without rendering it in any degree dangerous to the health of those who use it; for twenty-three parts of silver are sufficient to destroy all the noxious qualities of one part of copper.

Lastly, Silver is coined into money, and used as a sign of value for all sorts of commodities; but in this case it is alloyed with $\frac{1}{12}$ of copper, and is, of consequence only eleven penny-weights fine.

* British silver money is 11 penny-weights 2 grains fine. H.

C H A P. XXI.

Of Gold.

GOLD, the sun of the alchemists, is of all known metals the most perfect, and the least liable to alteration : its colour is a bright yellow. It is, next after platina, the most ponderous body in nature : In water it loses only between a nineteenth and a twentieth part of its weight : neither its hardness nor its elasticity is very considerable. Its ductility, of which gilding and gold wire afford such amazing proofs, is so great, that an ounce of gold is sufficient to gild a silver wire four hundred and forty-four leagues in length ; and it is reducible into leaves that may be carried about before the wind. It is calculated by Lewis, that a grain of gold will cover an area more than fourteen hundred inches square. It is the most tenacious of all metals ; for a wire of gold one tenth of an inch in diameter, is sufficient to support five hundred pounds weight without breaking. Gold soon becomes hard and brittle under the hammer ; but heat restores its ductility.

The colour of gold is subject to a good many varieties. It is sometimes more or less yellow or pale, and sometimes almost white: these differences, however, appear to be owing to some mixture. Gold has neither taste nor smell: It crystallizes by cooling into short quadrangular pyramids. Messrs Tillet and Mongez obtained it in this form.

Gold is found in nature almost constantly in a pure and virgin state. It is sometimes met with in small masses, either solitary or continuous, and in a bed of quartz: At other times it is in small spangles, among sand, at the bottom of rivers. Lastly, It is extracted from various ores, into the composition of which it enters; such as galena, blende, red silver ore, and virgin silver. It is almost always united with a certain quantity of silver, or some other metal, forming thus a natural alloy.

There are several varieties of native gold. It exists in plates, in grains, in crystals; which are either octahædral, in prisms of four faces, or striated in filaments, and in irregular masses. M. Sage thinks, that native gold in prisms is combined with a certain quantity of mercury, which renders it brittle.

Modern mineralogists reckon up various species of gold.

1. Native gold in union with silver, copper, iron, &c. It is found in Peru, Mexico, Hungary, Transylvania, &c.

2. Auriferous pyrites: It is not easily distinguished from other pyrites by the eye: we discover the gold by dissolving it in the nitric acid, and washing the residue. Gold is only mixed, not combined, in martial pyrites.

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Some arsenical pyrites, particularly those of Saltzbergh in Tyrol, contain likewise a little gold.

3. Gold mixed with silver, lead, and iron mineralized by sulphur. This auriferous ore is of a very mixed nature. According to M. Sage, it is found to contain blende, galena, specular antimony, copper, silver, and iron; the gold melts, and drops out with the lead, when the mass is exposed to heat. It comes from Naggyac in Transylvania.

Gold ore is assayed in different ways, according to its nature; pulverization and washing are sufficient with native gold. Gold alloyed with other metals must be roasted, melted, and cupelled with lead, and parted.

It is very easy to conceive in what way gold is extracted from its ores, after what has been already said on metallurgy in this work. Native gold needs only to be separated from its gangue. For this purpose, it is first pounded; then washed, to separate the powder of the gangue; then triturated in a mortar full of water, with 10 or 12 parts of mercury; the water being poured off after this operation, washes away every earthy particle from the metallic substance. When the amalgam, thus formed, appears to be sufficiently purified from earth, it is strained through goat-skins. Great part of the mercury passes through; a certain quantity remains still united with the gold. The amalgam is next heated, and the mercury separated from it by distillation; the pure gold obtained by this distillation is then melted, and run into bars or ingots. With respect to the gold that is found in combination in the ores of

other metals, such as lead, copper, silver, it is extracted by eliquation, cupellation, and parting. The lead which runs down from the eliquation of copper, carries with it the silver and the gold. It is then cupelled, to separate the lead ; and the silver, as we shall hereafter mention, is separated by parting.

Gold exposed to fire becomes red-hot before it melts. When very red, it assumes a dazzling lustre, and a clear green colour, like that of the aqua-marina. It does not melt till its colour change to a white red ; when cooled slowly it crystallizes. It suffers no alteration, however long it be exposed to fire, and however intense the heat ; for Kunckel and Boyle found gold to have undergone no alteration by being exposed for several months to the fire of a glass-house. This inalterability of nature is only relative, however, to the degrees of heat which we are capable of applying to it by the use of combustible matters ; for it appears that a much more intense and active heat, such as that of glass lenses, destroys the metallic properties of gold. Homberg observed, on exposing this metal to the focus of a lens of Tschirnhausen's, that it smoked, became volatile, and was even vitrified. Macquer observed, on exposing gold to the focus of M. Trudaine's lens, that it melted, and exhaled a smoke which gilded silver, and could therefore be nothing but gold volatilized ; that the globule of melted gold was agitated by a rapid internal motion, and became covered with a rough pellicle, shrivelled, and seemingly earthy ; and that a violet-coloured vitrification was at length formed in the middle of the gold. The vitrified part was by degrees enlarged, till it formed a kind of cap of a larger curvature than the globule
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of gold, and closely enclased in the gold in the same manner as the transparent cornea appears enclased in the sclerotic of the eye. The extent of the glass became gradually larger, and the gold was diminished. The surface on which it rests is always coloured with a purple tinge, which seems to be owing to the glass which it has absorbed.

Time did not allow Macquer to vitrify a given quantity of gold completely. He observed, that it would be necessary to reduce the violet glass with combustible matters, in order to know whether it would afford gold, and whether it were oxide of that perfect metal. At any rate, we are of opinion, that vitrified gold may be considered as a true oxide of gold; and we are the rather induced to adopt this opinion, because in a number of operations, which we shall immediately proceed to describe, it invariably takes a purple colour; and several preparations of it are used for giving this colour to enamel and porcelain. Gold, then, like other metallic matters, may be reduced to calx; only, like silver, it requires a more intense heat, and longer time to make it combine with the base of vital air, than any other metallic matter: these circumstances, no doubt, bear a near relation to its extraordinary density, and its faint tendency or aversion to combine with oxygen. It is reduced to a purplish oxide by electrifying it violently.

Gold suffers no alteration from the action of air. Its surface is only tarnished by the extraneous bodies which are continually floating in the atmosphere. Water does not alter it in any way; from the experiments of Garaye, however, it appears that this substance

stance gradually divides it in the same manner as iron.

Gold in its metallic state does not combine with earths or salino-terrene substances. Its oxide enters into the composition of glasses, and communicates to them a violet or purple colour.

Gold is not liable to suffer from the attacks of the sulphuric acid, however highly concentrated, and even assisted by heat.

The nitric acid dissolves a few particles of this metal; but it is perhaps rather mechanically than by true combination. Brandt was among the first chemists who asserted gold to be soluble in the nitric acid: the fact has been since confirmed by the experiments of Scheffer and Bergman. But we must observe, that, according to experiments made by the whole chemists of the Academy of Paris, the nitric acid produces this effect only in certain circumstances. M. Deyeux, member of the College of Pharmacy, has remarked, that the acid of nitre dissolves gold, only when it is ruddy, and contains nitrous gas. According to him, the acid is not pure in this state: he calls it *acid impregnated with gas*, and describes it as a kind of *aqua-regia*. We have elsewhere shown in what consists the difference between the nitrous and the nitric acid.

The muriatic acid alone, and in a state of purity, acts not upon gold in any sensible degree. Scheele and Bergman have discovered, that the oxygenated muriatic acid dissolves gold in the same way as *aqua-regia*; and forms also with the metal the same salt which it forms with the mixed acid usually employed to dissolve it. It is the excess of oxigene united with the muriatic acid which
causes

causes the solution to take place : it is accompanied with no sensible effervescence, like the other solutions of metals, by the oxygenated muriatic acid.

Aqua-regia has been considered as the true solvent of gold. It dissolves it, however, no better than the oxygenated muriatic acid. As it would be improper to repeat here what we have elsewhere said concerning the nature and properties of this mixed acid, and the varieties to which it is liable, according as the proportions of the two acids by the combination of which it is formed vary, we shall speak only of the manner in which it acts upon gold. As soon as the nitro-muriatic acid comes into contact with this metal, attacks it with an effervescence ; which, the more concentrated the acid, the hotter the temperature, and the more divided the integrant parts of the gold, is so much the more lively. This operation may be more speedily effected by a moderate heat ; at least a moderate heat is favourable in the beginning of the process. Bubbles then rise in constant succession, till a part of the metal be dissolved. This action by degrees ceases ; stirring or heat is requisite to make it continue. Nitrous gas is disengaged while the solution is taking place. The nitro-muriatic acid, when saturated with the full quantity of gold which it is capable of dissolving, takes a yellow colour of a lighter or a deeper shade. It is considerably caustic ; it tinges animal matters with a deep purple colour, and corrodes them. When evaporated with proper management, it affords crystals of a beautiful golden colour, resembling topazes, and appearing to be truncated octahædrons, and sometimes tetrahædral prisms. It is difficult enough to obtain this crystallization. M. Monnet thinks it

owing to a neutral salt, ready formed in the nitro-muriatic acid; and asserts, that in order to obtain it, the *aqua-regia* made use of should be composed of nitric acid with ammoniacal muriate, or muriate of soda. A mixed acid prepared in this manner cannot but contain nitrate of soda, or ammoniacal nitrate. It is either the one or the other of these neutral salts, according to the chemist whose opinion we are mentioning, which occasions the crystallization of gold. It appears, however, that a solution of gold in nitro-muriatic acid, made up of pure acids, is capable of affording crystals; and Bergman considers the salt as muriate of gold. These crystals, when heated, melt and take a red colour. This salt powerfully attracts the moisture of the atmosphere. A solution of gold gives, by distillation, a beautiful red colour, which is nothing but muriatic acid impregnated with a little gold. The alchemists who have laboured so much upon gold, called this liquor *red lion*. A few golden crystals are likewise sublimated, the colour of which is a reddish yellow. Most part of the metal remains at the bottom of the crucible; and fusion purifies it, so that it again displays all its properties.

The solution of gold may be decomposed by a great many intermedia. Lime and magnesia precipitate the gold in the form of a yellowish powder. Fixed alkalis afford the same phenomenon. But it is to be observed, that the precipitate is but very slowly formed; and the solution takes a reddish colour, if more alkali be employed than what is absolutely requisite; for the excess of alkali again dissolves the precipitated gold. The precipitate of gold may be reduced by heat in close vessels; it is an oxide which readily gives out its oxigene in the state

of

of vital air. This oxide, however, is fusible with vitreous matters, and communicates to them a purple colour; for enamels and porcelain are coloured with a precipitate of gold, formed by mixing a solution of gold with liquor of flints.

Gold precipitated by fixed alkali exhibits likewise another property, very different from those which gold possesses in its metallic state: it is soluble in pure sulphuric, nitric, or muriatic acid. All of these acids, when heated on the yellowish precipitate of gold, readily dissolve it; but they do not take up so much of it as to afford crystals. When these solutions are evaporated, the gold is very quickly precipitated; the same thing happens by rest. M. Monnet has observed a fact concerning the precipitation of gold by nut-gall*, which must not be forgotten; it is, that the precipitate which is reddish, dissolves very well in the nitric acid, and communicates to it a beautiful blue colour.

VOL. III.

K

Ammoniac

* As we have taken notice only of the precipitation of iron by nut-gall, we shall give a short account of the phenomena which this astringent substance exhibit with most other metallic substances.

Nut-gall, with the solution of cobalt, gives a clear blue precipitate; with the solution of zinc, an ash-green precipitate; with the solution of copper, a green precipitate, which becomes grey and reddish; with a solution of silver, it gives first reddish striz, which take afterwards the colour of burnt coffee; with the solution of gold, a purple precipitate. These facts have been observed and described by M. Monnet; and he has observed farther, that these precipitates are soluble in acids; and that alkalis combine with the latter solutions without producing precipitates.

The academicians of Dijon have added to these facts the following new observations. 1. The solution of arsenic is not altered by nut-

Ammoniac precipitates the solution of gold in much greater abundance. This precipitate is of a brown yellow, and sometimes of an orange colour; when exposed even to a moderate heat, it detonizes with a considerable noise; it has been called *fulminating gold*. Ammoniac is indispensibly necessary to its production. It may be formed, either by precipitating, by fixed alkali, a solution of gold made in nitro-muriatic acid, composed with ammoniacal muriate; or rather, by precipitating, by ammoniac, a solution of gold made in aqua-regia, composed of pure nitric and muriatic acid. The fulminating gold thus obtained is always one fourth more in quantity than the gold dissolved in the *aqua-regia*. There are some precautions necessary to be taken in order to escape suffering from the terrible effects of fulminating gold. In the first place, it must be dried cautiously, and in the open air, at a distance from any fire; for a very moderate degree of heat is sufficient to make it fulminate. As friction alone would be enough to make it give an explosion

gall; with the solution of bismuth, nut-gall produces a greenish precipitate; with the solution of nickel, a white precipitate; with the solution of antimony, a bluish grey precipitate; with lead, a stony sediment, the surface of which is covered with pellicles of a mixed green and red colour; lastly, the solution of tin takes a dirty grey colour, by mixture with nut-gall, and gives a copious precipitate, somewhat of a mucilaginous nature. Under the article of the Gallic Acid, or acid of galls, in the vegetable kingdoms, several of these facts will again draw our attention.

It may be proper to observe here, that the experiments of M. Monnet, and of the academicians of Dijon, were made with a decoction of the nut-gall: whilst those which will be taken notice of in the vegetable kingdom, refer to the action of the *gallic acid* on metallic solutions which accounts for the difference of the results in the two cases. F.

son, the vessels into which it is put must be stopped only with cork. Some unlucky accidents have shewn, that crystal stoppers, by their friction on the necks of the bottles, may cause such particles of the powder as adhere to that part of the bottle to fulminate; and by communication with the rest of the powder, to produce the most dangerous effects. A terrible accident happened in M. Baumé's laboratory, of which he has given an account in his *Theory and Practice of Chemistry*.

Chemists have entertained various opinions concerning the cause of the detonation of fulminating gold. Baumé gave it as his opinion, that in this instance there was formed *nitrous sulphure*, which he considered as the fulminating principle of this compound. But Bergman has proved his theory inadmissible, having formed fulminating gold without nitric acid, by dissolving a precipitate of gold in sulphuric acid, and precipitating it anew by ammoniac. Neither can the fulmination of this gold be owing to ammoniacal nitrate; for after being copiously washed in water, which would certainly carry off any portion of that salt which it might contain, it still retained its fulminating powers. On examining attentively what passes in the detonation of fulminating gold, it is observed to take fire at the very instant when it shivers into pieces. When it is exposed to the moderate heat of warm ashes, it gives out, before the explosion, sparks like those of electric fire; when exposed to the spark produced by the Leyden bottle, it detonizes; a simple spark without motion does not kindle it; lastly, after fulminating, it leaves the gold in a metallic state. It appears, therefore, that the fulmination of this gold is owing to some combustible matter contained in the compound.

pound. And as ammoniacal gas is necessary to the production of fulminating gold, it is at present agreed, that the explosion ought to be attributed to that substance. This theory is founded on the following facts.

1. M. Berthollet has obtained ammoniac gas by applying a gentle heat to copper tubes, containing fulminating gold, and communicating at one end by means of a syphon, with a pneumato-chemical apparatus with mercury. The gold was now no longer fulminating, but was reduced to oxide.

2. Bergman, having exposed fulminating gold to a degree of heat not sufficient to make it fulminate, gradually deprived it of its fulminating powers, by volatilizing the ammoniac gas which it contained.

3. When a few grains of fulminating gold are made to detonize in copper tubes, communicating with a pneumato-chemical apparatus with mercury, gas azote, and a few drops of water, are obtained as products, and the gold is found to be reduced. M. Berthollet, to whom we owe this fact, thinks that in this instance ammoniac is decomposed; that the hydrogen which it contains, uniting with the oxygen of the oxide of gold, reduces it by forming water; and that the gas azote, being thus set at liberty, is consequently disengaged: the fulmination appears therefore to be owing to the combustion of hydrogen, and the sudden disengagement of gas azote.

4. The concentrated sulphuric acid, melted sulphur, fat oils, and æther, deprives this precipitate of its fulminating powers, by detaching its ammoniac.

A singular property of fulminating gold, which shows
with

with what force it acts, is its making a mark or hole on any metal plate, such as a plate of lead, tin, and even silver, on which it is fulminated. But it does not appear to be liable to take fire in a very close vessel; for Lewis relates, that it produced no explosion when inclosed in an iron ball, and exposed to an intense heat. The cause of this phenomenon seems to be, that there is not then room for the disengagement of the gas azote. Bergman, who did not well know the nature of the gas disengaged during the fulmination of this precipitate, and considered it as pure air impregnated with a little ammoniac, has given a similar explanation of the experiments made on this matter before the Royal Society of London. The reader may consult his valuable Dissertation *de calce auri fulminante*, in his *Opuscula*. M. Berthollet discovered that oxide of silver, precipitated from nitric acid by lime, and digested with ammoniac till it take a black colour, acquires the property of detonizing, not only by a heat a very little superior to that of boiling water, but likewise by a slight friction against any body. Here, then, we have fulminating silver of a still more singular nature than the gold so called; which, however, owes its fulminating properties to the same cause. The ammoniac decanted from above this oxide, deposits, by slow evaporation, small, bright, lamellated crystals, possessing the property of fulminating, even under water, by simple friction.

The solution of gold is precipitated by alkaline sulphures. When the fixed alkali combines with the acid, the sulphur that is precipitated unites with the gold; but this combination is not very permanent; it is enough to heat the gold, and the sulphur is then volati-

lized, and the perfect metal left in a state of purity. It is proper to observe, that the gold precipitated from a solution by an intermedium, is perfectly pure, even more so than gold obtained by parting, being separated from the silver which it would otherwise have contained, in consequence of that metal being precipitated in the form of a muriate, even during the solution of the gold, as we have above observed.

Gold has not a greater affinity than all the other metals with the nitro-muriatic acid; on the contrary, almost any other metallic substance is capable of separating it from its solvent. Bismuth, zinc, and mercury, precipitate gold. A plate of tin immersed into a solution of gold separates this perfect metal into a powder of a deep violet colour, which is called purple precipitate of *Cassius*. This precipitate, which is used for painting on enamels and porcelain, is prepared by diluting a solution of tin in nitro-muriatic acid, with a large quantity of distilled water, and pouring upon it a few drops of a solution of gold. When the solutions are pretty much concentrated, there is instantaneously formed a precipitate of a red crimson colour, which in a very few days changes to purple: the precipitate is light, and somewhat mucilaginous; the liquor is filtrated, and the precipitate washed and dried. This matter is a compound of oxide of tin and oxide of gold; the preparation of it is one of the most singular operations of chemistry, on account of the variety and the inconstancy of the phenomena which attend it. Sometimes it affords a beautiful red precipitate; sometimes its colour is only a deep violet: and what is most surprising, it happens pretty often, that the mixture of these two solutions

itions produces no precipitate. Macquer, to whom these varieties were very well known, observes, that they depend almost always on the state of the solution of tin employed. If the solution have been hastily effected, the metal is too much oxidated, and there is too little of it contained in the solution for the acid of the solution of gold to act upon it; for he attributes the formation of the purple precipitate of *Cassius* to the action of that acid upon the tin. According to him, to succeed in this operation, the solution employed must have been very slowly made, so as to contain as much tin as possible, without the metal being too much oxidated. He accordingly gives the following direction, for preparing the purple precipitate. Dissolve the tin, one part after another, in an acid consisting of two parts of nitric acid, and one of muriatic acid, with an equal weight of distilled water; on the other hand, dissolve with the help of heat, a quantity of very pure gold in another mixed acid, consisting of three parts of nitric and one of muriatic acid. Dilute this solution of tin in an hundred parts of distilled water; divide it into two parts; add to one of them a new quantity of water, and try both of them with a drop of the solution of gold; observe then which of them affords the most beautiful red, and treat the other in the same manner with it; then pour in the solution of gold till it cease to afford a precipitate.

Lead, iron, copper, and silver, possess likewise the property of separating gold from its solution. Lead and silver separate it into a dirty dark purple precipitate. By copper and iron it is precipitated with its metallic lustre. The nitric solution of silver, and that of sulphate

of iron, produce likewise a red or brown precipitate in a solution of gold.

Neutral salts act not in a very conspicuous manner on gold. Only it is observed, that borax melted with this metal alters its colour, and gives it a strange paleness: but nitre and muriate of soda restore it to its former state. A solution of borax poured into a solution of gold, forms a precipitate of boracic acid, impregnated with gold.

Sulphur is incapable of combining with gold; and this mineral is therefore employed to separate such other metals as happen to be united with gold, especially silver. The alloy is melted in a crucible; when it is fully melted, flowers of sulphur, or sulphur in powder, are cast on its surface: the sulphur melting, and combining with the silver, thus forms a blackish scoria, which swims above the gold. It is to be observed, that the two metals are never entirely separated by this operation, which is called *dry parting*; and that it is applied only to lumps of silver containing too little gold to be worth the expence of parting by aquafortis.

Alkaline sulphure dissolves gold entirely. Stahl even thinks, that it was by such a process that Moses made the Israelites drink the golden calf that they had worshipped. In making this combination, a mixture, consisting of equal parts of sulphur and potash, is hastily melted with a quantity of gold leaf, amounting to an eighth part of the weight of the whole mass. This melted matter is poured upon a surface of porphyry, pulverized, and diluted with hot distilled water; it now forms a yellowish green solution, containing an auriferous

ferous sulphure of potash. This metal may be precipitated by means of acids, and separated from the sulphur precipitated together with it, by heating it in open vessels.

Gold combines with most metallic matters; and in its combinations with them exhibits a number of important phenomena.

It unites with arsenic. This metal renders its texture brittle, and its colour very pale. It is scarce possible to separate the arsenic entirely from this mixture; the gold seems to render it more fixed in its nature.

We are unacquainted with any alloy of gold with cobalt. It combines with bismuth, which renders it white and brittle; in the same manner with nickel and antimony. As these metals are all easily oxidated, and mostly fusible, they are easily separated from gold by the joint action of fire and air.

Sulphure of antimony has been loudly praised by the alchemists as a purifier of gold. When this metal is alloyed with any extraneous metallic substance, such as copper, iron, or silver, on melting with it sulphure of antimony, the sulphure unites with these substances, and separates them from the gold, which is found by itself at the bottom of the vessel. This gold, however, is alloyed with antimony; it is purified by heating it to a white red. The antimony is then volatilized; a very intense fire, however, is requisite to separate it entirely; and it is observed, the antimony carries with it some part of the gold. This process, which was so famous among the alchemists, is in no way preferable to that

that in which sulphur alone is employed for the same purpose.

Gold easily unites with zinc : the mixed metal resulting from this union is the whiter, and the more brittle, in proportion as the quantity in which the zinc enters into the mixture is greater. An alloy consisting of equal parts of these two substances is of a very fine grain ; and takes so beautiful a polish, that it has been recommended by Hellot as proper for making mirrors to telescopes, not liable to lose their lustre. When the zinc is separated from the gold by calcination, the oxide of the zinc is reddish, and carries with it a little gold, as mentioned by Stahl.

Gold has a greater affinity than any other metallic substance with mercury, and decomposes amalgams of any other metal with mercury. It unites with mercury in all proportions, forming with it an amalgam ; which the greater the proportion of the gold, is so much the more solid and the higher coloured. This amalgam is liquified by heat, and crystallized by cooling, like almost all the other compounds of this kind. We know not well what regular form it takes. M. Sage says, that its crystals are like feathered silver ; and that, when viewed through the magnifier, they appear to be quadrangular prisms. He asserts likewise, that the mercury becomes fixed in this combination. This amalgam is used for gilding in *water-gold*.

Although gold cannot be oxidated by the joint action of the air and the fires of our furnaces, it suffers that change, however, when heated with mercury. Mercury, with a forty-eighth part of gold, heated in a flat-bottomed matrass with a very narrow neck, on a sand-bath,

bath, in the same way as oxide of mercury is heated in preparing *precipitate per se*, is itself oxidated, and causes the same phenomenon to take place on the gold. The mixture is changed into a dark red powder; and this double oxide is obtained even much sooner, according to M. Baumé, than oxide of mercury heated by itself.

Here, then, we have a metal which, though exceedingly difficult to oxidate by itself, hastens and facilitates the oxidation of another metallic matter, which does not readily suffer such a change by itself.

Gold enters very readily into union with tin and lead: either of these metals totally destroys its ductility. With iron it forms a very hard alloy, of which, instruments for cutting may be formed much superior to those which are made of pure steel. This mixed metal is grey, and subject to the attraction of the magnet. Lewis proposes the use of gold to solder small pieces of steel neatly, and in a very solid manner.

Gold combines with copper, which renders it red, hard, and more fusible. This alloy is fixed at different proportions for pieces of money, vessels, and oys.

Lastly, Gold combines with silver, which changes its colour, and renders it very pale. A certain difficulty, however, attends this mixture, on account of the different gravities of the two metals; as has been observed by Homberg, who saw them separate when melted together. The alloy of silver with gold forms the jeweller's *green gold*.

As the use of gold is very extensive, and as men have agreed to use gold and silver as common signs to represent

represent the value of all the other productions of nature and art, it is of great importance to be able to distinguish the degree of the purity of any piece of this metal, in order to the prevention of fraud, and that all the gold which circulates in commerce may be nearly of the same intrinsic value. Just and severe laws have prescribed the particular alloy of gold to be employed in making utensils, and have pointed out the proportions requisite to give it a due degree of hardness and inflexibility for that purpose. Chemistry affords means for distinguishing with what quantity of any other metal, gold may be at any time alloyed. The operation by which this is accomplished is called *the assay of gold*: Twenty-four grains of the gold to be assayed are cupelled for this purpose, with forty-eight grains of silver, and four drachms of pure lead. The lead as it vitrifies carries off with it the imperfect metals, such as copper, &c. The gold remains, after the cupellation, in combination with the silver. These two metals again are separated by an operation which bears the name of *parting*. To part an alloy of gold and silver, is to separate the two metals by a solvent, which may act upon the silver without affecting the gold. Aquafortis is commonly used. The design in adding the silver to the gold was, that all the silver in the gold might be completely dissolved by the nitric acid; for experience has shown, that gold must contain at least twice its weight of silver, before the nitric acid can act so as to dissolve the silver totally. As three parts of silver are often added to the gold, this operation is called *quartation*, as the gold composes in fact but one-fourth part of the mixture.

mixture. The following is the way of performing this process of *parting*.

The cupelled alloy of gold and silver is first hammered flat, care being taken to heat and turn it frequently, that it may not split, nor separate into small parts, in consequence of becoming hard and brittle under the hammer: it is then rolled up in feathers in a spiral form; in this form it is put into a small matrafs, and ~~fix~~ drams of precipitated aquafortis, unmixed with muriatic acid, but diluted with half that quantity of water, are poured upon it. The vessel is exposed to a moderate heat, till the mixture begin to effervesce. The silver is soon after dissolved, and the metallic coil takes a brown colour. When the acid ceases to act, it is then decanted off; and a new quantity is poured upon the metal, and boiled on it till the silver be entirely dissolved. This second operation is called a *repetition*. The acid is then decanted off, and the spiral piece of metal, now become very thin, and perforated with a great many holes, is washed; it is poured with water into a crucible; the water decanted off, the crucible made red-hot, and the gold now displays all its properties. It is next weighed, and its weight shows the degree of the fineness of the gold. In order to know exactly what quantity of other metals gold contains, any mass of gold whatever is supposed to consist of twenty-four parts, called *carats*; and to attain still greater accuracy, each carat is divided into two and thirty parts, called *thirty-seconds of a carat*. If the gold thus assayed have lost one grain in twenty-four, the mass to which it belonged is considered as gold of twenty-three carats; if a grain and an half, it is then gold of

is given to the following preparation : Pieces of linen steeped in a solution of gold, dried and burnt. In making use of them, a wet cork is dipped in these ashes, and rubbed upon silver ; on which the gold, being in a state of extreme division, readily fixes. We have already spoken of gilding with water-gold. To make use of it, the piece of copper to be gilded must first be well scoured with sand and a weak aquafortis, which the workmen call *second water* ; it is then immersed into a very weak solution of mercury : the mercury being precipitated, causes the amalgam of gold, which is applied to the piece, after washing it with water, to carry away acid, to adhere. When the amalgam is uniformly extended over the copper, the piece is then heated on the coals, to volatilize the mercury ; the operation is concluded by rubbing upon the gold gilder's wax, which is composed of *red bole*, *verdigris*, *alum*, or *martial vitriol*, with yellow wax, and heating the gilt piece for the last time to burn the wax.

The other uses of gold for toys and laces are sufficiently known, so that it is unnecessary for us to insist on them here. With respect to the medicinal virtues which have been ascribed to it, the best physicians at present agree in denying their existence, and think that any effects produced by the several potable preparations of gold must have been owing not to the gold, but to other matters mixed with it in the solution.

CHAP.

A valuable gold mine has been lately discovered in Ireland. Gold is still found in spangles, in the brook of Glengonar, in Crawford-Muir, in Scotland. Gold exists naturally in all vegetables. It is highly probable, notwithstanding the experiments of the French Academy, that nitric acid, however pure, always dissolves a certain proportion of gold subjected to its action, in the ordinary process of parting. H.

C H A P. XXII.

Of Platina.

PLATINA, which has been known as a peculiar metal only during the last forty years, has not yet been found any where but in the gold-mines of America, particularly in that of Santa Fé, near Carthagena, and in the bailiwick of Choco in Peru. The Spaniards have given it this name from *plata*, which in their language signifies silver; comparing it with this metal, of which it has in fact the colour: But the name of *white gold* appears to agree much better with its nature than that of *small silver*; for in its properties it resembles gold much more than silver.

Before the period which we have mentioned, there were some toys of platina. But as this metal cannot be melted and wrought by itself, it is probable that the snuff-boxes, heads of canes, and other utensils of this kind, sold under the name of *platina*, were mixtures of that metal, with some other metallic substances; which, as we shall see, are necessary to render it fusible.

The platina in cabinets is in the form of small grains or spangles of a livid white, inclining at once to the colour both of iron and of silver. These grains are mixed with various extraneous substances; they are found to contain spangles of gold, blackish ferruginous sand; grains which, when viewed with the magnifier, appear to be scorified like *machefer*, and some particles of mercury. The mercury is separated from this mixture by heating it; washing carries off the sand and the grains of iron; the iron may likewise be separated by the magnet: after this there remains nothing but gold and platina, which may be easily separated by picking, as Margraff has done. The grains of platina, when examined with the microscope, appear, some of them triangular, others round and flat, like small cakes. When hammered upon steel, most of them are found to be malleable and ductile: some of them break into pieces on such an occasion. These, when narrowly examined, are found to be hollow, and to contain within, iron and a white powder. It is, doubtless, on the principle of their containing ferruginous particles, that the property which some grains of platina possess of being subject to the attraction of the loadstone, however purified from ferruginous sand, is to be accounted for.

This metal is very nearly as hard as iron. The specific gravity of platina, mixed with the several extraneous matters which we have mentioned, is nearly equal to that of gold: in water it loses from a sixteenth to an eighteenth part of its weight. Buffon and M. Tillet, on comparing, by weight, equal bulks of platina and gold reduced to grains like those of platina, found the specific gravity of platina to be one twelfth less than
that

that of gold. It has been ascertained by later experiments, that platina, after being purified by a long fusion, is superior in specific gravity to gold.

Probably platina is not found in the mines in the same form in which it is brought to us ; it possibly owes its granulated form to the waters which carry it down from the hills into the plains. It is sometimes found in pretty considerable pieces : the Society of Biscay are in possession of a piece as large as a pigeon's egg. Platina, being found in places adjacent to gold-mines, always contains a certain quantity of that metal. As to the mercury mixed with it, this metal has been employed in extracting the gold.

Though toys made of platina have long been sold, yet the peculiar nature of the metal was unknown. Even the workers of mines had not paid any particular attention to it ; but neglected a matter which had no very beautiful aspect, and was besides very difficult to work. For our first knowledge of platina, we are indebted to a Spanish mathematician, Don Antonio de Ulloa, who accompanied the French academicians that were sent on the famous journey to Peru, to ascertain the figure of the earth. In the account of his journey, published at Madrid in the year 1748, he makes mention of this metal. Charles Wood, an English metallurgist, had brought some of it from Jamaica in the year 1741. He then examined it, and gave an account of his experiments in the Philosophical Transactions for the years 1749 and 1750. At that period, the greatest chemists in Europe engaged eagerly in the examination of this new metal, the singular properties of which promised to render it so useful. Scheffer, a

Swedish chemist, published an account of his experiments on platina, in the Memoirs of the Academy of Stockholm for 1752. Lewis, an English chemist, made a series of experiments, almost complete, upon this metal, which may be found in the Philosophical Transactions for the year 1754. Margraff has given a detail of his experiments on this new metal in the Memoirs of the Academy of Berlin for 1757. Most of these separate memoirs have been collected into one body by M. Morin, in a work entitled, *Platina, white gold, or the eighth metal, Paris 1758*. About the same time, Messrs Macquer and Baumé jointly made many important experiments on platina; an account of which has been published in the Memoirs of the Academy for the year 1758. Buffon, in the first volume of the Supplement to his Natural History, gives an account of a train of experiments on platina, made by himself, M. de Morveau, and the Count de Milly. The Baron de Sickengen likewise engaged in a series of researches on the metal of which we are now speaking; but his work has not yet been published in French. Macquer gives an extract from it in his Chemical Dictionary. M. de Lille has presented to the Academy a paper on platina. The scarcity of the metal, and the difficulties attending the treatment of it, have retarded our progress towards a complete knowledge of its properties: but of late the inquiries concerning it have been resumed with new ardour. Bergman, M. Achard, and M. de Morveau, have examined this metal in respect to several of its properties, which were before but little known.

Platina, when purified and separated by washing, picking, and muriatic acid, from the extraneous bodies which it contains, suffers no alteration of nature, only
 conglomerating

conglomerating a little more by exposure to the most intense heat. All the chemists who have examined the metal agree in this. Messrs Macquer and Baumé kept platina for a number of days exposed to an unremitting fire in a glass-house, without producing any other alteration on its grains, but that of making them adhere slightly together; and they were even so feebly agglutinated as to be separable barely by touching them. In these experiments, they observed, that platina acquired a lustre when heated to a red white; that when very long exposed to heat, it took a dirty grey colour; and, lastly, that, as Margraff had asserted, it constantly increased in weight; which could only happen in consequence of its being reduced in part to oxide; a change which it appears liable to suffer from the action of fire. Those chemists exposed platina to the focus of a burning glass: it first smoked, and gave out very red and lively sparks; the portions of metal exposed to the centre of the focus were next melted in about the space of a minute: the melted parts were of a sparkling white colour, and in the form of a button; they were divisible into plates with a knife. One of these masses of melted platina being struck upon steel, became flat, and was reduced into a plate without splitting or cracking: it became hard and brittle under the hammer. This fine experiment shows platina to be fusible by extreme violence of fire; to be malleable like silver and gold; and to be liable to very little alteration from the action of fire: for in all of these experiments, most of which were performed in the open air, the platina exhibited no marks of being oxidated. M. de Morveau likewise effected the fusion of platina by heating it in the wind-

furnace described by Macquer, with his reductive flux, consisting of eight parts of pounded glass, one part of calcined borax, and half a part of charcoal in powder. At present it is very easily melted in small portions, without the addition of any other substance, by heating it on a burning coal with a stream of vital air : but the globules, thus melted, are so very small, that they can answer no purpose.

Platina suffers no alteration from exposure to the air : we know not, however, what might happen, if it were kept for a long while red-hot, in contact with air : perhaps it would be oxidated, as Juncker asserts that silver and gold are, when heated in this way.

This metal suffers no alteration from water, earthy matters, salino-terrene substances, or alkalis.

Neither the sulphuric acid, however highly concentrated, the nitric, nor the muriatic acid, however strong and fuming, act at all on platina, even though assisted by ebullition. Distillation, a method which chemists have always found very effectual in promoting the action of acids on metallic matters, does not effect any solution or alteration of these mixtures ; only, the sulphuric acid has been observed by Messrs Lewis and Baumé, to tarnish the colour of grains of platina. The nitric acid again improves their lustre. Margraff says, that he obtained, by distilling this acid with platina, towards the end of the operation, a little arsenic ; which phenomenon has not been observed by any other chemist. The muriatic acid produces no change on platina. Margraff likewise obtained, by distilling this acid on the metal, a white sublimate, which appeared to him to be arsenic, and a reddish sublimate, the quantity

city of which was so small, that he could not examine its properties. All of these substances are evidently extraneous to platina. This metal, therefore, resembles gold, in being but little subject to be affected by the action of simple acids; but still more in being soluble in the oxygenated muriatic, and in the nitro-muriatic acid.

The first of these acids dissolves platina with ease, and without requiring the assistance of any considerable heat: Fifteen or twenty degrees of heat in the atmosphere are sufficient to promote this solution: it takes place without any sensible effervescence; and, in other respects, perfectly resembles the following solution.

The nitro-muriatic acid, which is the most powerful solvent of platina, is that consisting of equal parts of nitric and muriatic acid. To effect this solution, which is generally more difficult than that of gold, an ounce of platina must be put into a retort, and a pound of nitro-muriatic acid, consisting of the above-mentioned proportions, mixed with it: the retort must then be put on a sand-bath, and a receiver fitted to it. As soon as the acid becomes hot, there issue from it some bubbles of nitrous gas, not in great plenty. The mixed acid acts calmly and slowly: this acid, however, takes at first a yellow colour, which changes to an orange, and becomes gradually deeper, till it be changed into a very dark brown red. When the solution is ended, particles of reddish and black sand are found at the bottom of the retort, and are separated by decanting off the liquor; the saturated liquor gradually deposits small irregular crystals of a dusky colour, which are a combination of the acid with platina. The solution of platina is among the highest coloured of metallic so-

lutions. Though it appears to be of a deep brown colour, yet when it is diluted in water, the fluid takes at first an orange colour, which in a short time becomes yellow, and very like the solution of gold: it communicates to animal matters a blackish brown tinge; which, however, is by no means purple. M. Baumé says, that platina, melted in the focus of a burning glass, and dissolved in aqua-regia, never takes a brown colour, like that of platina in grains; and that the solution is of a deep orange yellow.

Macquer asserts, that on evaporating the solution of platina, and suffering it to cool, crystals are obtained from it, much larger, and much more beautiful, than those which it deposits of itself when saturated. Lewis, on suffering this solution to evaporate in the open air, obtained crystals of a deep red colour, tolerably large, of an irregular form, and pretty like the acid of benzion, but thicker. Bergman describes them as having an octohædral form. This salt is tart, but not very caustic; it melts with heat, gives out its acid, and leaves, as a residue, a dark grey oxide. The concentrated sulphuric acid produces in it a dark-coloured precipitate, which is no doubt sulphate of platina. The muriatic acid likewise produces in it, in the course of time, a yellowish sediment.

Alkalis and salino-terrene matters decompose the solution of platina, and precipitate the metal in the state of oxide. Carbonate of potash produces an orange precipitate in the solution of platina. This precipitate is not a pure oxide of platina. Messrs Macquer and Baumé have observed, that it owes its colour to its containing a certain quantity of acid. It is therefore to be considered

dered as a mixture of oxide of platina with muriate of potash, or a kind of triple salt. A proof of this opinion is, that when this precipitate is washed with hot water, the fluid acquires a colour by dissolving the salt of platina, and the residue is pure oxide of platina, of a grey colour. Fixed alkali, boiled on this precipitate, instantly deprives it of its colour, leaving an oxide of platina of a grey white pearl colour, according to the experiments of M. Baumé. That chemist made himself certain, that the precipitate of platina is soluble in alkali; for, on pouring a solution of the metal into a hot solution of carbonate of potash, he found no precipitate produced: and this solution, precipitated by fixed alkali, always retains on this account a deep colour; and platina may be easily obtained by evaporating it to dryness. Margraff discovered, that soda does not precipitate the solution of platina: but Bergman has observed, that, on putting into it a great quantity of this alkali, there is a precipitate speedily enough produced.

The alkaline Prussiates form a copious blue precipitate, which, according to M. Baumé, is owing to the iron contained in the alkali; for if the Prussiate of potash be purified by the process which that chemist describes for the purpose, from the iron which it contains, it no longer affords any more than a few particles of blue, which are owing to the metal's still retaining a small portion of iron. Bergman asserts, that an alkaline Prussiate, highly saturated and very pure, does not precipitate the solution of platina; and that this metal is the only one not liable to be precipitated
by

by this re-agent; and therefore proposes it for separating the iron which is always in union with platina.

Cautic ammoniac produces an orange precipitate in the solution of platina. This precipitate is almost entirely saline; for water dissolves most part of it, taking a colour like that of the solution of gold. After the water has acted on this precipitate, there remains a blackish substance, which appears to be ferruginous. One essential difference between the precipitate of platina and that of gold by ammoniac, is, that the former is not fulminating like the latter.

Nut-gall, or rather the gallic acid, produces, in the solution of platina, a deep green precipitate, which becomes gradually pale by rest.

All precipitates of the solution of platina obtained by alkaline matters, are incapable of being vitrified, and of colouring glass by furnace-fires. In the attempts made by Messrs Lewis and Baumé to accomplish this, the platina was always reduced to grains, which were arranged in ramifications, or a kind of chequer work. Platina may be obtained in a sort of button, by exposing these precipitates to heat, together with some reductive fluxes, such as borax, cream of tartar, glass, &c. Messrs Macquer and Baumé, melted, in five and thirty minutes, at a forge-fire, blown by two strong bellows, a precipitate of platina mixed with these fluxes. They obtained in a hard blackish glass, like bottle-glass, a brilliant button of platina, which appeared to have been in fusion. This button was not ductile: it broke into two pieces; in consequence of which it was observed to be hollow within. It was nearly of the same hardness with forged iron, and made deep scratches in
gold,

gold, in copper, and even in iron. Notwithstanding what we have observed of precipitates of platina, as not being liable to vitrify or mix with glass, Baumé melted them into a vitriform matter, by two different processes. The precipitate of platina, mixed with calcined borax and a very fusible white glass, and exposed for six and thirty hours to the heat of the hottest place of a furnace for pottery, afforded him a greenish glass, inclining to yellow, and containing no globules of reduced metal. This glass being treated anew with cream of tartar gypsum, and potash, was thoroughly melted, but contained small globules of platina dispersed through it. M. Baumé separated them by washing, and found them to be ductile. He then, in conjunction with M. Macquer, exposed precipitate of platina in the focus of the same burning-glass with which they had melted the metal. The precipitate emitted a very thick luminous smoke, which diffused a strong smell of nitro-muriatic acid: it lost its red colour, and resumed the natural colour of platina; and it melted into a glossy sparkling button: which button was an opaque vitrescent matter, of an hyacinth colour on the surface, and blackish internally, and may be considered as a real glass of platina. It is, however, necessary for us to observe, that the saline matters with which it was impregnated, must, without doubt, have contributed to its vitrification.

The precipitate of platina does not appear to be soluble in simple acids; but it dissolves readily in the nitro-muriatic acid, to which it communicates only an orange colour; never a brown like platina in grains.

The solution of platina is not precipitated by alkaline or perfect neutral salts; but ammoniacal muriate produces

duces in it a copious precipitate. We know not yet well what passes on this occasion. It appears, that the orange colour obtained by pouring a solution of ammoniacal muriate into a solution of platina, is a true saline substance entirely soluble in water. This precipitate possesses one property of no small importance, which was first observed by M. de Lisle; it melts alone, without any addition, in a good strong furnace-fire, or in the fire of a common forge. The platina melted by this process is a sparkling button of considerable density and closeness of grain, but not malleable, and not liable to become ductile, unless when exposed to a pretty strong heat. Macquer is of opinion, that the same thing takes place in this instance of fusion, as when grains of platina are exposed by themselves to the action of a strong fire; and that what is affected is nothing but an agglutination of the particles softened by the heat; which being much more minute than grains of platina, are brought more completely into contact with each other than those grains can be; in consequence of which, though no real fusion take place, yet the grain of the metal is much closer in this than in the former case. It appears, however, that as platina in grains is liable to melt in a burning-glass, and acquires, by that means, considerable ductility; so the precipitate of this metal produced by ammoniacal muriate, being in a state of extreme division, may be also melted; and if the precipitate acquire not by fusion the same ductility with platina melted by the rays of the sun, this is perhaps owing to its still retaining some matter which was intermixed with it when it was precipitated; but may be separated from it by the action of fire.

Margraff

Margraff dissolved platina in *aqua-regia*, consisting of sixteen parts of nitric acid, with one of ammoniacal muriate. On distilling this solution to dryness, and even till the retort became red-hot, a dark red salt was sublimated, and the residue was a reddish powder. It is not known whether the solution of platina in simple *aqua-regia*, that is, *aqua-regia* consisting of nitric and muriatic acid, would afford the same sublimate by distillation.

Messrs Margraff, Baumé, and Lewis, mixed the solution of platina with solutions of the other metallic substances. From these experiments it appears, that almost all metals precipitate platina in a brick-red or a brown powder; and that, agreeably to what happens to most other metals, none of these precipitates possesses the properties of a metal. In this there is an analogy between gold and platina: with tin, however, platina does not give a purple, but a brown precipitate, inclining to red. With respect to the effects which the several metallic solutions produce on the solution of platina, we shall only observe, that solutions of bismuth and lead by the nitric acid, of iron and copper by any of the acids, and of gold by *aqua-regia*, produce, none of them, any precipitate in the solution of platina, according to Margraff: but again, solutions of arseniate of potash, of nitrate of zinc, and nitrate of silver, are capable of precipitating the solution of platina: with the first, it yields a scanty crystallized precipitate of a beautiful golden colour; with the second, an orange-red matter; and with the third, a yellow matter. These different precipitates have not been yet carefully examined; nor is it known by what decomposition they are produced.

Scarce any of the neutral salts acts upon platina. Margraff heated platina with sulphate of potash and sulphate of soda at a strong fire. The salts were melted, but the platina remained in grains without alteration; only it communicated a faint reddish colour to the saline matters, which it was enabled to do, no doubt, by means of the iron mixed with it.

Nitre, according to the experiments of Lewis and Margraff, alters platina in a singular manner. No detonation takes place when a mixture of these two substances is cast into a crucible; but when a mixture, consisting of one part of platina and two of nitre, is exposed for a considerable time to an intense heat, as Lewis exposed it for three days and three nights successively, the metal takes a rusty appearance. If this mixture be boiled in water, the fluid dissolves the alkali, which carries with it a brownish powder; and the platina separated by this washing is found to be one third less than the original quantity. The brown powder may be separated from the alkali by filtration. This powder appears to be a kind of oxide of platina, mixed with a little oxide of iron. Lewis caused it to take a whitish grey colour, by distilling it many times successively with ammoniacal muriate. Margraff repeated this valuable experiment, and has added two important facts; platina combined with alkali of nitre, and diluted in a certain quantity of water, forms a jelly: A portion of the metal separated from this jelly, by dilution in water and filtration, takes a black colour like pitch.—From these circumstances, it appears, that the platina suffers in this process some great alteration; and it is wished, that these experiments were farther prosecuted,

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in order to determine whether by repeated oxidation with nitre, this metal might be wholly reduced to a brown powder; as also to ascertain the state of the platina thus oxidated.

Muriate of potash or soda, borax or earthy salts, produce, none of them, any alteration on platina, nor contribute in any degree to its fusion. Ammoniacal muriate sublimated with this metal affords a small quantity of *marital flowers*, on account of the iron contained in the platina.

Chemists have not agreed with regard to the mutual action of arsenic and platina. Scheffer first gave out that arsenic acted as a flux to platina; but the experiment succeeded only in part with Lewis, and did not succeed at all with Margraff, Macquer, and M. Baumé. This experiment has been since repeated; and it is now established as a fact, that arsenic does cause platina to melt very readily; and that the mixture produced by this fusion is exceedingly brittle. When the arsenic is separated by roasting, and the perfect metal exposed to a continued heat, the latter becomes ductile. By this process, M. Achard and M. Morveau have accomplished the making of crucibles of platina, by melting it a second time in moulds.

No attempt has yet been made to combine cobalt, nickel, or manganese with platina.

This perfect metal enters readily enough into combination with bismuth; which renders it fusible, and the more so the greater the quantity of the bismuth.— This mixture is brittle; it becomes yellow, purple, and blackish in the air; it cannot be cupelled without the

greatest difficulty ; the mass has always very little ductility.


Platina easily melts with antimony : the product is a brittle metal with facets, from which the antimony may be separated by the action of fire, but which still retains, whatever means may be used for its separation, so much of the antimony as is sufficient to destroy the gravity and ductility of the platina.

Zinc renders platina very fusible, and combines very easily with it ; the mixture is brittle, and resists the file : it inclines to blue in colour, when the platina is more copious than the zinc. These two metallic matters are separable by the action of fire, which volatilizes the zinc ; platina, however, always retains a little of it.

Platina does not combine with mercury ; and though triturated together for hours, these two metallic matters cannot be formed into an amalgam. It is also known, that in America mercury is employed to separate platina from gold. Various intermedia, such as water, which Messrs Lewis and Baumé made use of, and nitro-muriatic acid, which M. Scheffer employed, contribute nothing to the union of platina with mercury. It resembles iron in this property, as also in colour and hardness.

Platina readily combines with tin. The mixture is very fusible, and melts into a flowing liquid. It is so brittle as to break even by a blow, when the two metals are united in equal parts. When tin is in the proportion of twelve or more parts to one of the platina, the mixed metal is then sufficiently ductile ; but its grain is coarse, and it becomes yellow in the air. The platina diminishes the ductility of the tin in an amazing degree, and it does not appear that any advantage can be derived

red from this mixture. However, when well polished, it remains long in the air without suffering alteration. Lewis, to whom we owe most of our knowledge concerning the mixtures of platina, oxidated the metal, and dissolved it in muriatic acid by means of the tin.

Lead and platina combine very well by fusion; but a stronger fire is requisite to melt them than to melt the foregoing mixture. The platina destroys the ductility of the lead. From the combination of these two metals there results a mixed metal, nearly of a purple colour, more or less brittle according to the proportions of the platina, striated and granulated in its fracture, and liable to alter very readily in the air. Cupellation of lead was one of the most important experiments to be made on platina; for this was the only operation that could be expected to separate from it such extraneous matters as it might contain. Lewis, and several other chemists, in vain attempted to cupel platina in common cupelling furnaces, whatever the degree of the heat employed in those furnaces. On account of the excess of the lead, it is vitrified and absorbed in the beginning of the operation; but the platina soon becomes fixed, and the progress of the operation stops; the perfect metal remains in union with a portion of the lead, and is without ductility. Messrs Macquer, and Baumé effected the complete cupellation of platina, by exposing an ounce of this metal with two ounces of lead to the heat of the hottest place of the porcelain-furnace at Seves. The wood fire that they kindled in it burned for fifty hours uninterruptedly. At the end of that time the platina lay flat upon the cupel: its upper surface was dark and shrivelled, and was easily separable from the ; its

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under surface was brilliant ; and what is of most importance, it was now sufficiently malleable. These chemists ascertained, by every possible means, the platina to be very pure, and unmixed with lead. M. de Morveau likewise succeeded in cupelling a mixture of a dram of platina with two drams of lead in Macquer's wind-furnace. This operation, which was four times repeated, lasted eleven hours. M. de Morveau obtained a button of platina, not adhesive, uniform, coloured like tin, somewhat rough, weighing exactly a dram, and not subject to the attraction of the magnet. This is therefore a convenient process, by which platina may be melted into plates that may be wrought in the forge ; and of consequence made into various utensils of great value for their hardness and unalterability. M. Baumé likewise observed it to possess this valuable property, that different pieces of it may be foldered and wrought together like iron, without the intervention of a third metal. After heating two pieces of platina that had been cupelled in the furnace of Seves to a white red, he put the one upon the other, and struck them with a hammer ; and by this management the two pieces were as sufficiently and solidly foldered as any two pieces of iron could have been. It is not necessary that we should insist long on this experiment, to show what advantages the arts may derive from it.

Lewis could not obtain a mixture of forged iron and platina. A mixed metal of this kind would possess at once the hardness of tempered steel, and a considerable degree of ductility ; it would not at least be so brittle as steel. The English chemist, whom we have cited, melted a mixture of cast iron and platina. The alloy was

to hard that the file could make no impression upon it: it had little ductility; but when red-hot it broke with a smooth fracture.

Platina communicates hardness to copper, and melts with it easily enough. This mixture is ductile when the proportion of the copper is three or four times that of the platina. It takes a fine polish, and is not liable to be tarnished in the course of ten years.

Platina destroys in part the ductility of silver, increases its hardness, and tarnishes its colour. The mixture is very difficult to melt. The two metals are separable by fusion and rest. Lewis observed, that the silver melted with platina is dashed with a kind of explosion against the sides of the vessel. This phenomenon seems to be effected solely by the silver; for M. d'Arcet saw that metal burst bowls of porcelain, in which it was inclosed, and spring out of those vessels in consequence of the action of the fire upon it.

A very strong heat is requisite to make platina combine properly with gold. It greatly alters the colour of that metal, at least if its quantity be not very small; for instance, a forty-seventh part of platina, and all proportions under that, produce but little alteration on the colour of gold. Platina scarce diminishes the ductility of gold; it is even one of those metals which have the least influence on gold this way. The gravity of platina being greater than that of gold, might be an encouragement to fraud; and the Spanish ministry have therefore prohibited the exportation of the metal. However, since chemical methods of distinguishing when gold is alloyed with platina have been discovered, these fears are now vain; and it is much to be wished, that pla-

platina were permitted to be an article of commerce, that ~~so~~ we might obtain the use of a new metal, which promises to be so serviceable.

The solution of ammoniacal muriate possesses, as we have observed, the property of precipitating platina. When, therefore, gold is suspected to be alloyed with platina, a solution of it in *aqua-regia* may be assayed with a solution of ammoniacal muriate. If it contain any platina, however little, an orange or reddish precipitate will be produced: if there is no precipitate produced, this circumstance is a proof that the gold contains no platina. If the valuable properties of platina should one day render it more scarce and more esteemed than gold, neither will we then be in danger of having alloys of gold with platina imposed upon us for pure platina; for a solution of sulphate of iron, which possesses the property of precipitating a solution of gold without affecting platina, might be used as a test to prevent such imposition. A plate of tin immersed into a solution of platina, alloyed with gold, would likewise detect the presence of the latter metal, by becoming coated with a purple precipitate; whereas platina by itself gives it only a dirty brown colour, inclining to red. Besides, the precipitate of platina does not colour glass; whereas the precipitate of gold gives it a purple colour.

All these properties of platina which we have examined prove it to be a peculiar metal. Its possessing in so low a degree the properties of ductility and fusibility, which has been considered by some persons as a strong objection against this opinion, is not sufficient to justify the refusing it that character which we have ascribed to it: for perhaps the difference between the fusibility of
platina

platina and that of forged iron, is not so considerable as the difference between the fusibility of forged iron and that of lead : and its inductility may be considered as owing to its having never yet been completely melted. With respect to the opinion of those philosophers who think platina a natural alloy of gold with iron, however ingenious and satisfactory it may appear, it cannot be admitted till such time as platina shall be separated by an exact analysis into these two metals, and till it be better imitated than at present by an artificial mixture of gold with iron. Lastly, Macquer has urged a very strong objection against this last opinion, by observing, that the more thoroughly platina is purified from iron, the more remote does it appear in its exterior characteristics and properties from the nature of gold.

It may be easily conceived with what advantages the use of this precious metal in commerce would be attended, as it possesses, with the durability of gold, nearly the hardness of iron, and is proof against the action of the most violent fire, and the most concentrated acids. It would, doubtless, be of the highest utility both to chemistry and to the arts.

The density and opacity of platina render it valuable for the construction of optical instruments. The Abbé Rochon has constructed a mirror of this metal, the effect of which greatly surpasses that of the mirrors made of steel and other metals. Like other metallic mirrors, it reflects but a single image ; but is at the same time as unchangeable as the mirrors of glass. H.

C H A P. XXIII.

Genus VI. *Bitumens in general* *.

BITUMENS are combustible matters, either solid, soft, or fluid, of a strong, acrid, aromatic smell, and apparently of a much more compound nature than any of the bodies belonging to the mineral kingdom which we have yet examined. They are found either in strata in the bowels of the earth, or dropping from rocks, or swimming on the surface of waters. They generally burn with a rapid flame when heated in contact with air, like those matters formed by the organs of animals and vegetables, which are called *oils*. They do not admit of being so exactly analysed as earthy, saline, or metallic matters; for the action of fire alters them in a singular manner, extracting from them principles, which, as they are volatilized, re-act on each other. In this respect,

* The reader may here recollect, that we divided combustible mineral matters into five genera; diamond, hydrogenous gas, sulphur, metals, and bitumens. F

Effect, there is an analogy between bitumens and vegetable and animal substances. They afford, by distillation, an odorate water phlegm, more or less coloured and saline; an acid generally concrete; sometimes ammoniac; and oils, which, though at first light, become more and more thick and coloured, as the distillation is continued, and the strength of the fire increased. After this analysis, there remains a coal of a greater or a less bulk, dense, light, porous, brilliant; or compact, according to the particular nature of the bitumen. This analysis is a proof that these inflammable bodies have originated from animal or vegetable matters; as we shall relate more at large when we give the history of their properties.

Bitumens suffer some alterations from light; when fluid, their colour is rendered deeper, and their smell modified in transparent vessels. The air renders them thicker by a gradual evaporation of the moisture which they contain; and the drier the atmosphere, so much the speedier is this evaporation. Their odorous principle, or spiritus rector, is at the same time gradually dissipated; and from fluid they become by degrees tenacious and solid. But this latter alteration requires a long series of years.

When bitumens are boiled in water, the water does not dissolve them, but extracts their spiritus rector, and afterwards exhales that odour which is peculiar to them. It would therefore appear, that water has a greater affinity with their odorous principle than the oily matter of the bitumen; and perhaps these bodies might thus be entirely deprived of smell.

No experiments have been made to determine in

what manner the saline-terrene substances act upon bitumens. Both lime and pure alkalis, however, appear capable of combining with these combustible matters, and forming with them compounds soluble in water, which are called *soaps*.

We know not in what manner the mineral acids are capable of acting on bitumens. Probably they would either dissolve or burn them like oils, according to the state of concentration in which they happened to be.

Neither has the action of neutral salts, hydrogenous gas, sulphur, or metals, on bitumens, been examined; and the chemical properties of these bodies are in general but very little known. This is an unbeaten path; and very useful discoveries might here be made.

Naturalists have been at much more pains in studying the origin and formation of bitumens, than chemists in analysing them. Several different opinions have been entertained on this head. Some have thought combustible bodies to belong properly to the mineral kingdom, and to hold in it the same rank which oils and resins hold among organic matters. But this fancied analogy, however plausible, does not agree with facts; for we know of no substance in the mineral kingdom of an oily nature. And that opinion which ascribes the origin of bitumens to vegetable matters buried underground, and altered by the action of mineral acids, has been much more generally received than the former. Every fact, indeed, concerning bitumens, concurs to prove, that they have been produced from organic matters. Near them are found a great many matters
still

still retaining an organical form. Besides, their chemical properties are those of substances formed by the action of vital powers ; and they have been imitated to a certain degree by the combination of oils with concentrated sulphuric acid. In the chemical history of vegetable matters, we shall see, that this acid brought into contact with essential oils, renders them hard and black, and communicates to them a strong pungent smell like that of bitumens. But are these bodies formed solely from vegetables buried under ground, as has been asserted by most naturalists ? Do animal matters, in the same situation, never contribute to the formation of bitumens ? One objection which may be urged against the opinion that represents bitumens as originating solely from particular vegetable bodies, is the great disproportion between the masses of bitumen found in the earth, and the wood or trees found near them, and still more the trifling quantity of oily matters contained in those vegetable substances. And farther, the abundance of these combustible bodies, in places where scarce any remains of vegetable matters appear, but the exuviae of animals are found in heaps above the bitumens, leads us to think, that these latter organic beings have contributed greatly, perhaps more than vegetables, to the formation of certain bituminous substances. We may likewise observe, that the successive strata, in which some continuous masses of bitumen are found arranged in the interior parts of the globe, indicate those masses to have been deposited slowly, and by water ; and that the date of their formation corresponds to the period in which such immense masses of shells, and other marine bodies, have been formed by the sea. They have therefore been in

a fluid state, and have become hard in the course of time, in consequence of being exposed to the action of saline or other substances, abounding in the interior parts of the earth. Such is the opinion which M. Parmentier, Member of the College of Pharmacy, has embraced concerning the origin of mineral coal, in a Memoir which he read before that Society at the opening of their course of lectures. The oils and fats of marine animals appear therefore to be part of the materials which Nature employs in the formation of certain bitumens : and there are others again, the origin of which is evidently from vegetables, and which have been produced from resins or essential oils, buried and altered in the earth.

The number of bitumens is very considerable. Naturalists have arranged them under various genera. Considered chemically, they merit rather to be considered as so many species ; for the same chemical characteristics are common to them all. Some of them are liquid ; others of a soft consistency : there are others solid, and among these some so hard as to be susceptible of polish : others friable. We know of five species, considerably distinct from one another. These are amber, the asphaltes or bitumen of Judæa, jet, pit-coal, and petroleum ; and we are to give their history. Ambergris we do not consider as a bitumen but, as an animal product.

C H A P. XIV.

Species I. *Of Amber, and its Acid.*

THIS substance is, in external appearance, one of the most beautiful of bituminous matters : it exists in irregular fragments of a yellow or brown colour, either transparent or opaque, and composed of layers or scales. It takes a very fine polish. After being rubbed for some time, it becomes electric, and attracts straws. The ancients, who knew amber to possess this property, gave it the name of *electrum*, and hence the word *electricity*.

The consistency of this bitumen is pretty hard, nearly equal to that of certain stones ; which has induced several authors, particularly Hartman, a naturalist who lived about the end of the last century, to rank it among precious stones. It is, however, brittle and friable.—When pulverized, it diffuses an agreeable enough smell. It is often found to contain insects in a good state of preservation ; a circumstance which proves that it has been in a liquid state, and in that state has inclosed these
bodies.

bodies. It is usually buried under ground, at various depths ; it is found under coloured sand, in small incoherent masses, on beds of pyritous earth : above it, is found wood containing a blackish bituminous matter. From these circumstances, it is thought to be formed from a resinous substance, altered by the sulphuric acid of the pyrites. It also floats on sea-coasts. It is gathered on the shores of the Baltic in Ducal Prussia. The hills of Provence, near the town of Sisteron, the marquifate of Ancona, and the duchy of Spoleto in Italy ; Sicily, Poland, Sweden, and various other countries, likewise afford this substance. This bituminous substance is distinguished into a good many varieties, by its colour, contexture, transparency, or opacity. Walerius reduces them to the following

Varieties.

1. White transparent amber.
2. Pale yellow transparent amber.
3. Citron yellow transparent amber.
4. Transparent amber of a golden yellow colour. *Chryso-electrum* of the ancients.
5. Dark red transparent amber.
6. White opaque amber. *Lucelectrum*.
7. Yellow opaque amber.
8. Brown opaque amber.
9. Amber coloured green or blue by extraneous matters.
10. Veined.

Were we to take notice of all the accidental appearances which are observed in the interior parts of pieces of amber, we might extend these varieties to a much more considerable

considerable number. But, in regard to the price demanded for pieces of amber, on account of their size, their transparency, and their containing insects in a fine state of preservation, it is proper to warn people that they may not be imposed upon; as many persons know how to render it transparent, or colour it at pleasure, as well as to soften it to a degree, that extraneous bodies may be introduced into it. Wallerius informs us, that gold-coloured amber always owes its transparency to nature; and that amber made transparent by art is always of a pale colour.

Although it be highly probable, that this bitumen originates from resinous vegetable matters; yet several naturalists have entertained different opinions concerning its formation. Some have thought it to be urine of certain quadrupeds, congealed and hardened; others have imagined it a juice of the earth, extracted and carried off by the sea, which being driven by the waters on the shore, is there dried and hardened by the rays of the sun. This class of naturalists call it a peculiar mineral juice. Such was the opinion of an ancient naturalist of the name of Philemon, quoted by Pliny. It has been in modern times revived by George Agricola. Frederick Hoffman thought it to consist of a light oil, separated by heat from bituminous wood, and thickened with the acid of vitriol. This opinion of Hoffman's, however, cannot be admitted: it is not easy to imagine how an oil separated in the bowels of the earth could happen to contain animals that are known to live only on the surface. Till of late, amber was thought to be a resinous juice, which dropped at first in a fluid state from certain trees: this juice, it was thought, having
been,

been, by some convulsion of the earth, buried underground, had been there hardened, and impregnated with saline mineral vapours. But there is no appearance of its having been altered by concentrated acids; for experience shows, that such acids would have blackened it, and reduced it to a carbonaceous state. Pliny thought amber to be nothing, but the resin of the pine-tree condensed by cold. M. Girtanner thinks it to be a vegetable oil concreted by the acid of the ants. The *formica rufa* of Linnæus is, according to this author, the species which prepares it. These insects inhabit old forests of fir-trees, where there is fossil amber found, which is ductile, like liquid wax, but becomes dry in the air.

A considerable degree of heat is necessary to liquify amber: it becomes soft, and swells a good deal. When heated in contact with air, it takes fire, and diffuses a very thick and strong-smelling smoke. Its flame is yellowish, variegated with green and blue. After its combustion there remains a sparkling black coal, which affords, by incineration, a very small quantity of brown earth. Bourdelin, in his Memoir on Amber (*Academy*, 1742), relates, that he obtained only eighteen grains of this earth from two pounds of amber burnt in a roasting pot. Half a pound of the same bitumen, burnt and calcined in a crucible, afforded, in a second operation, twelve grains of earthy residue; from which, by means of the magnet, he extracted iron.

Amber distilled in a retort, by a fire gradually applied, gives at first a phlegm which takes a red colour, and is plainly of an acid nature. This acid spirit retains a strong smell of amber; there passes next a volatile acid salt, which crystallizes in the neck of the retort

into small white or yellowish needles ; next after this salt, there comes a white light oil of a very lively smell. This oil gradually takes a colour as the fire becomes stronger, and at length becomes brown, blackish, thick, and viscid, like empyreumatic oils. While these two oils are passing, there is a certain quantity of volatile salt sublimated, which becomes gradually more and more coloured. After the operation, there remains in the retort a black mass fixed on its bottom, brittle, and similar to the bitumen of Judæa. George Agricola made this observation three centuries ago, on the residue of distilled amber. When the operation is conducted with a moderate fire, judiciously applied, and the quantity of the amber not inconsiderable, these products may be obtained separately by changing the receiver. They are commonly received all in one receiver, and afterwards rectified by a moderate heat. The acid loses its colour in part by this rectification. The oil, the reason of which becoming black towards the end of the operation, is because it carries with it a portion of carbonaceous matter, and because the acid re-acts on its principles,—may be rendered very white and very light by repeated distillation. Rouelle, the elder, has given a very good process for obtaining it in this state by one operation. Put the oil with water into a glass alembic, and distil it by the heat of boiling water ; the purest portion, being the only part of the oil volatile at such a degree of heat, on account of its levity, passes with the water, and is collected above it. To preserve it in this state, it must be put up in stone-vessels ; for in glass-vessels, the rays of light which pass through that matter, give it, in a certain time, a yellow, or even a brown colour.

This

This analysis proves amber to consist of a great quantity of oil rendered concrete by an acid. It contains likewise a very small quantity of earth the nature of which has not been yet examined, and a few particles of iron.

The oil of amber appears to be much of the same nature with essential oils. It is equally volatile, and has the same smell. It is very inflammable; and appears to be fit for forming soaps with alkalis.

The volatile salt of amber was for some time considered as an alkaline salt. Glafer, Le Fevre, Charas, and John-Maurice Hoffman, professor at Altdorf, were of this opinion. Barchusen, and Bouldoc the father, both in the last century, were the first who ascertained the nature of this salt to be acid. Their discovery has been unanimously received by succeeding chemists; who have not agreed, however, concerning the particular nature of that acid. Frederick Hoffman, because amber is found in Prussia under strata of matters among which pyrites are copiously intermixed, has inferred its salt to be vitriolic acid. Neumann appears to be of the same opinion. Bourdelin, in the Memoir above quoted, relates several experiments, by which he sought to ascertain the nature of this salt. He first observes, that the salt of amber, extracted by distillation, however white and pure it may appear, always contains an oily matter; to this oily substance, no doubt, it owes its smell, and that kind of combustibility which it constantly exhibits when cast on burning coals. He attempted by various means to separate that substance. We shall have occasion to see, when we come to examine the nature and properties of alcohol, that it could not serve his purpose.

He

He succeeded no better by digesting fixed alkali over amber, with a view to separate from it this oily matter; the alkali only dissolved a little of the bitumen, and acquired a saltish lixivial taste, like that of sea-salt. Lastly, the best means which Bourdelin could find for combining the acid of amber entirely purified from oily matters with fixed alkali, was to detonize a mixture, consisting of two parts of nitre, with one of the bitumen. The residue, after this detonation, he lixiviated with distilled water. The lixivium was of an amber colour: it produced, in the solution of silver, a white curdled precipitate; in the solution of mercury, a precipitate of the same colour. It decomposed, in like manner, several other metallic solutions; but Bourdelin considered only these two precipitations as conclusive facts. He understood them as indicating the acid of amber to be the same with that of marine salt; for these phenomena are precisely the same with those which the acid of marine salt produces in the nitric solutions of mercury and silver. The lixivium of the residue which remained after the detonation of amber with nitre, being evaporated in the air, afforded a mucilaginous matter, in the middle of which oblong square, crystals were by degrees deposited; which, by their form, their saltish taste, their decrepitation on burning coals, and still more their effervescence, which was considerable, and the smell of muriatic acid which exhaled from them, when concentrated sulphuric acid was poured upon them, indicated, in his opinion, that they consisted of muriatic acid, with a base of nitre. Notwithstanding this analysis, which, considering the time when Bourdelin made his experiments, is very accurate, the

chemists who have since examined the salt of amber have not found it to bear any resemblance to the mu-
fiatic acid. Bergman, who seems to have adopted this
opinion, gives the following account of the properties
and the elective affinities of this salt. The succinic acid
or acid of amber, extracted by distillation, and purified
by repeated solutions and crystallizations, forms, with
potash and ammoniac, crystallizable and deliquescent
neutral salts. With soda, it affords a salt which does
not attract the moisture of the atmosphere: with barytes
and lime, it forms salts that are scarce soluble: with
magnesia, a thick gum-like matter. It dissolves metal-
lic oxides; and the succinates produced by these solu-
tions are mostly crystallizable and permanent.

Barytes, lime, and magnesia, according to him, se-
parate the acid of amber from alkalis. Barytes decom-
poses succinates of lime and magnesia; and lime-water
precipitates magnesia from its combination with this
acid.

The chemical properties of this bitumen have been no
farther examined. We know not even how the acids
would act upon it. Frederick Hoffman affirms, that it
may be entirely dissolved in a lixivium of caustic alkali,
and in sulphuric acid. We know, too, that the essential
oil of amber combines with caustic ammoniac, and forms
with it, simply by mixture and shaking, a sort of liquid
soap, of a milk-white colour, and of a very pungent
smell, known in pharmacy by the name of *Eau de lue*:
and lastly, this same oil is known to dissolve sulphur by
the heat of a sand-bath, thus composing a medicine,
called *succinated balsam of sulphur*.

Amber is used in medicine as an antispasmodic: it
has

has been recommended for hysteric and hypochondriac cases, a suppression of the *menfes*, gonorrhœa, fluor albus, &c. It is made use of after being washed with warm water, and levigated to a fine powder. It is used in fortifying and resolvent fumigations, by throwing the powder on a hot brick, and directing the smoke to the place upon which you wish it to act. The volatile spirit and the salt of amber are considered as incisive, cordial, and antiseptic; they are also administered as powerful diuretics. Oil of amber is applied both externally and internally for the same purposes as amber itself: it is administered in smaller dozes, on account of its acting with more energy. The succinated balsam of sulphur is given in dozes of a few drops in certain drinks, or mixed with other substances in pills, and is successful in pituitous affections, or defluxions of the breast and kidneys, &c. A syrup, called *syrup of amber*, is made up of spirit of amber and opium, and is successfully used as a calming, an anodyne, and an antispasmodic medicine. *Eau de luce* is prepared by pouring a few drops of oil of amber into a phial full of caustic ammoniac, and shaking the mixture till it take a milk-white colour. It has been long used in fainting-fits as a powerful stimulant: it is put to the nostrils, and it then stimulates the nerves; and, by the sneezing which it excites, the fluids are again put into motion, and the patient restored.

The most beautiful pieces of amber are cut and polished into vessels, heads of canes, necklaces, bracelets, snuff-boxes, &c. But this species of toys is no longer valued among us, since diamonds and cut stones have

been known and brought into use. They are sent, however, to Persia and China, and to other foreign countries, where they are still valued as the greatest curiosities. Wallerius says, that the most transparent piece may be used for microscopes, burning-glasses, prisms, &c. It is affirmed, that the late King of Prussia was possessed of an amber burning-glass a foot in diameter, and that in the cabinet of the Duke of Tuscany there is a column of amber ten feet high, and of a most beautiful lustre. Two pieces of this bituminous substance may be joined together, by dipping them into a solution of potash, heating them, and applying them to each other.

CH A A

C H A P. XXV.

Species II. *Of Asphaltus.*

ASPHALTUS, or *bitumen of Judea*, called also *funeral gum*, *amber of Sodom*, *mountain-pitch*, *balm of mummies*, &c. is a black bituminous substance, ponderous, solid, and considerably brilliant. It breaks easily, and its fracture is vitreous. A thin plate of this bitumen appears red between the eye and the light. Asphaltus, when cold, has no smell; when rubbed, it emits a faint smell. It is found on the waters of the lake Asphaltites, or the Dead Sea, in Judea, near which stood the ancient cities of Sodom and Gomorriha. The inhabitants of the adjacent country, finding the smell of the bitumen, which gathers on the waters of that lake, troublesome, and the bitumen itself a profitable article of commerce, collect and expose it to sale. Lemery, in his Dictionary of Drugs, says, that asphaltus sweats like liquid pitch out of the earth covered by the Dead Sea; and rising above the waters, is there condensed by the heat of the sun, and the action of a salt which abounds in those waters. It is also found on many lakes in China.

The asphaltus of commerce, M. Valmont de Bomare tells us, is obtained from the mines of Daunemore, and especially in the principality of Neufchatel and Wallengin. According to that naturalist, it is of two colours, either blackish or greyish. But such asphaltus is far from being pure; it seems to be only earth hardened, and intermixed with bitumen which has penetrated through it.

Naturalists are divided concerning the origin of asphaltus, as well as concerning the other bitumens. Some think it a mineral product, formed of an acid united in the interior parts of the earth, with some fat matter. Others think it a resinous vegetable matter, that has been buried under ground, and altered by mineral acids. The most general and probable opinion is, that it has been produced in the same way as amber, and is actually nothing but amber altered by the action of subterraneous fire. The ground of this opinion is, that amber, when melted and deprived of a part of its oil, becomes black, dry, brittle, and in all respects like asphaltus. But it can be finally established only by a comparative analysis of this residue of amber and asphaltus. Asphaltus has not yet been examined with such exactness as will allow us to presume on the analogy between them.

Asphaltus, when exposed to fire, becomes liquid, swells, and burns with a thick flame and smoke; the smell of which is strong, acrid, and disagreeable. By distillation, it affords a coloured oil, like brown petroleum, and an acid phlegm.

Asphaltus is used by the Arabians and Indians in the
same

same way as pitch for coating their vessels. It enters into the composition of the black varnishes which we get from China, and of those artificial fires which burn on water. The Egyptians used it in embalming dead bodies; but it was employed for that purpose only by the poor, who could not afford to purchase dearer antileptic matters. Wallerius asserts, that the merchants prepare a sort of asphaltus of thick pitch, or by mixing and melting pitch with asphaltus from Judea. But the fraud may be detected by means of alcohol, which entirely dissolves pitch, but produces no change on asphaltus, only taking itself from it a pale yellow colour.



C H A P. XXVI.

Species III. Of Jet.

JET, in Latin *gagas*, called by Pliny *black amber*, by Strabo, &c. *pangetis*, is a black bituminous substance, compact, hard like some stones, brilliant and vitreous in its fracture, and susceptible of a fine polish. After being rubbed for some time, it attracts light bodies, and, like amber, appears to be electric. It has no smell: when heated, it acquires a smell nearly the same with that of the bitumen of Judea.

Jet is found in France, in Provence, and in the county of Foix. There is also a quarry of it which is wrought at Belestat in the Pyrenees. It is found too in Sweden, in Germany, and in Ireland. The quarries of jet are in strata; they likewise contain pyrites and pit-coal, and most of the other bitumens.

This bitumen, when exposed to a strong heat, becomes soft and melts; it burns with a foetid odour. By distillation, it affords oil and an acid liquor.

Of the several opinions which have been advanced concerning the formation of jet, the most probable is that which represents it as asphaltus condensed and hardened by length of time. It has been adopted by the learned Wallerius.

Jet is used for mourning toys. At Wirtemberg it is wrought into bracelets, buttons, boxes, &c.

C H A P.

C H. A. P. XXVII.

Species IV. *Of Pit-coal.*

THE name of *fossil-coal*, *pit-coal*, *stone-coal*, *liban-trax*, &c. is given to a black bituminous matter, foliated, either glistering or dull, brittle, and inferior in consistency and purity to the bitumens which we have been describing.

This bitumen derives its name from its combustibility, and the use to which it is in many countries applied. It is found in the interior parts of the earth, under stones of various degrees of hardness, and under aluminous and pyritous schisti. These schisti always bear impressions of vegetables belonging to the fern-tribe, which have been observed by Bernard de Jussieu to be mostly exotics. Pit-coal is sometimes nearer to, sometimes more remote from, the surface of the earth. Its disposition is always in horizontal or inclined layers; oftenest in inclined. The beds or strata which it composes differ from each other in consistency, colour, gravity, &c. Over this bitumen, strata

of fossil-shells and madreporès, varying in extent, are often observed ; a circumstance which has led some moderns, particularly M. Parmentier, to think that it has been formed in the sea by the deposition and alteration of the oily or fat matters of marine animals. Most naturalists think it the residue of wood deposited in the ground, and altered by acids.

Quarries of fossil-coal are wrought like mines of metal by digging into them pits and galleries, and hewing down the coal with a sort of pick-axes. The colliers are often in danger of losing their lives by the elastic fluids disengaged. This mephitic, which they call *choak damp*, puts out their lights, and seems to be carbonic acid gas. There likewise gathers in these mines a kind of inflammable gas, the effects of which are very noxious, and which sometimes produces very dangerous explosions.

Fossil-coal is very plentiful in nature. It is found in England, Scotland, Ireland, Hainault, the territory of Liege, Sweden, Bohemia, Saxony, &c. Several provinces of France afford great quantities, particularly Burgundy, the district of Lyons, Forez, Auvergne, Normandy, &c.

Fossil-coal is distinguished by its hardness, or friability into stone-coal or earth-coal. The manner of its burning, and the phænomena which it exhibits during combustion, afford the best characteristics for distinguishing it into different species. Wallerius arranges fossil-coals, considered in this point of view, under three species. 1. The scaly coal, which remains black after combustion. 2. The compact foliated coal, which affords, after being burnt, a spongy matter like scoræ. 3. Fibrous pit-coal,

coal, resembling wood, which is reduced to ashes by combustion.

This bitumen, when heated in contact with a burning body and air, takes fire; the more slowly, and with the greater difficulty, the more ponderous and compact it is: when it has once taken fire, it diffuses a lively lasting heat, and burns long before being consumed. It may be quenched and burnt again, for a number of times successively. The inflammable matter contained in it appears to be very dense, and in a manner fixed in some other incombustible substance, which opposes its combustion. It exhales as it burns a peculiar odour; which, however, is no way sulphureous, if the coal be very pure, and contain no pyritous matter. The combustion of this bitumen seems very analogous to that of organic matters, as it may be stopped and afterwards renewed. The most volatile part of the oily combustible matter contained in pit-coal is indeed burnt and dissipated when it is first exposed to the action of heat; and if, after the whole of that principle is dissipated, the combustion be stopped, the bitumen retains only the most fixed and the least inflammable part of its oil, in a truly carbonaceous state, and combined with an earthy base. It is by a process of this nature that the English prepare their *coaks*, which are nothing but pit-coals deprived by the action of fire of the fluid part of their oil.

We may easily observe what happens in this operation, by heating this bitumen in close vessels, and in a distillatory apparatus. It affords in this way an alkaline phlegm, concrete ammoniacal carbonate, and an oil which, as the distillation proceeds, takes a deeper colour,
and

and becomes more ponderous. There passes at the same time a large quantity of an elastic inflammable fluid, which is commonly thought to be oil in vapours, but is properly hydrogenous gas, mixed with azotic gas, with carbonaceous matter dissolved in it, and with carbonic acid gas. There remains in the retort a scorified carbonaceous matter, which is still susceptible of combustion, and is the same with the English *coak*. Observing carefully the action of fire on pure pit-coal, we perceive the coal to be first softened, and in a manner half melted. Some species of pit-coal do not experience this fusion, or rather softening, from the action of caloric. These species would seem to contain less oil than those which soften in the fire: but the last are the most frequent, and the best. The distinction of the pit-coal into different kinds, is far from being so exact as it will be made hereafter. M. Faujas has thrown some new light on this subject, in a Dissertation, published by him a few months since, on pit-coal. But as this property might render it unsuitable for the melting of ores, it must be deprived of it before it be applied to that purpose. After taking from it the principle which renders liable to soften, that is, the oil which it contains in great abundance, and thus reducing it to a state nearly the same with that of vegetable coal, it then becomes suitable for the fusion of ores. Let us not forget to observe, that the ammoniac which pit-coal affords in such considerable quantity, affords an argument in favour of that opinion which represents this bitumen as produced from animal matters; for, as we shall hereafter see, bodies belonging to the animal kingdom always afford this salt when distilled. This analysis is performed in the

great way in various places in England; and the several products are collected in a peculiar distillatory apparatus. The oil is used for pitch; the ammoniac is used in the composition of ammoniacal muriate; and the residue is a very good *couk*. M. Faujas de Saint Fond has imported this useful art into France; and the trials which he has made in the king's garden have succeeded very well in the small way: We have as yet no establishment for carrying it on in the great way*.

Pit-coal is highly useful in countries destitute of wood. It is used as a combustible matter; and the dangerous effects which have been ascribed to it are quite imaginary. The sulphureous vapour which it has been said to diffuse has no existence; for chemists have universally found, by the most exact analysis, that pure mineral coal contains not an atom of sulphur. From this we see the ignorance and imposture of some people who have pretended to give processes for purifying coals of sulphur. Another consideration which should induce us to make as much use as possible of coals in France is, that such enormous quantities of charcoal are consumed in the working of ores, that our wood is likely to fail one day or another; it is especially in works of that kind we should try the use of pit-coal, as the English have long done. It is already beginning to be used in various manufactories among us; and in the famous founderies of iron at Creusot, near Montcenis in Burgundy, there is a great instance of its application to these purposes, highly worthy of imitation.

Purified

* The English reader will here recollect the patriotic exertions of the Earl of Dundonald to establish works of this kind in Britain. H.

Purified pit-coal is nothing but that which has been deprived of its oil by the action of fire. This sort of coal burns without smoke, without softening, and without diffusing any strong smell; in a word, it is a true *coak*; and is, on account of these properties, preferred for fires in rooms.

Another inconvenience, beside the copious dark smoke proceeding from it, which attends the burning of pit-coal, is, that the copious and rapid stream of air requisite to maintain it in combustion, carries before it, and volatilizes, a part of the ashes. But both these inconveniences may be in a great measure remedied by a judicious construction of chimneys; so that the current of air, and whatever matters mix with it, may be entirely carried up, and discharged in the air, and no part of it returned and dispersed through the room.

This combustible matter will in France be applied with most advantage for the service of arts and manufactures of all kinds; in consequence of which, wood may be greatly saved for kitchen and room fires, and for building.

C H A P. XXVIII.

Species V. Of *Petroleum*.

THE name of *petroleum*, or *oil of stone*, has been given to a liquid bitumenous substance which runs between stones upon beds of rocks, or in various places on the surface of the earth. This oil is of various degrees of levity, smell, consistency, and inflammability. Authors take notice of a great many varieties of it. The lightest, the most transparent, and the most inflammable *petroleum*, they have distinguished by the name of *naphtha*. *Petroleum*, properly so called, is a liquid bitumen, somewhat thick, and of a deep brown colour: mineral pitch, again, is a black bitumen, thick, scarce liquid, tenacious, and adhesive to the fingers: The following varieties have been described by Wallerius, and several other naturalists.

Varieties.

1. White naphtha.
2. Red naphtha.

3. Green or dark naphtha.
4. Petroleum mixed with earth:
5. Petroleum trickling through stones.
6. Petroleum swimming on waters.
7. Mineral pitch, or *maltha*.
8. Piffasphaltus. It is of a middle consistency, between that of common petroleum and that of asphaltus, or bitumen of Judea.

The several sorts of naphtha are found in Italy, in the duchy of Modena, and on Mount Chiaro, about twelve leagues from Placentia. Kempfer, in his *Amanitates Exotice*, relates, that great quantities of it are gathered in many places in Persia. Petroleum runs in Sicily, and in many places of Italy; in France, at the village of Gabian, in Languedoc; in Alsace, at Neufchatel in Switzerland; in Scotland, &c. Piffasphaltus and mineral pitch were formerly obtained from Babylon, in the building of the walls of which they had been employed; from Ragusa in Greece, and from the pond of Samofata, the capital of Comagenia in Syria. It is at present obtained from the principality of Neufchatel and Wallengin, from the Well de la Page, a league from Clermont-Ferrand in Auvergne, and from various other places.

With regard to these several varieties, it is to be observed, that they seem to be all produced from one common origin, and to be but different modifications of the same substance. Most naturalists and chemists ascribe the formation of petrolea to the decomposition of solid bitumens by the action of subterraneous fires. Naphtha,

they observe, appears to be the light oil which is first disengaged by fire: that which follows after it, having colour and consistency, forms the several sorts of petroleum: And, lastly, petrolea, united with earthy substances, or altered by acids, acquire the characteristics of mineral pitch, or pissasphaltus. The phenomena of the distillation of amber favour this opinion: It affords actually a sort of naphtha, and a petroleum too, of a higher or a lighter brown colour, according to the degree of heat employed, and the length of time spent in the operation. Lastly, They observe, that nature often affords all the different sorts of petroleum in the same place, from the lightest naphtha to mineral pitch. Such are the fluid bitumens from Mount Festin, in the duchy of Modena. Although this opinion be very probable, yet other authors think petroleum an oily mineral combination, formed by the sulphuric acid with some fat matters. But even such a combination must still be allowed to originate from organic beings; as fat matters are always formed by those beings.

The chemical properties of petroleum have not yet been examined. We know only, that naphtha is very volatile, and so combustible, that it takes fire when brought near any burning body; it even appears by its volatility to attract the flame. From brown petroleum there is obtained an acid phlegm, and an oil which at the first resembles naphtha, but acquires a colour as the distillation proceeds. There remains in the retort a thick matter like pissasphaltus, which by greater activity of fire may be rendered dry and brittle like asphaltus, and entirely reduced to a carbonaceous state. Alkalis scarce act upon petroleum: the sulphuric acid colours

and thickens it; the nitric acid kindles it, in the manner as essential oils: it easily dissolves sulphur; coloured by metallic oxides; and it combines with and with the help of heat softens and dissolves a of it.

Several kinds of petroleum are used for various uses in the countries in which they abound. Kempfer says, they are used in Persia, to give light, and in lamps with wicks. They may also be used for bon fires. Lehman says, that for this end the oil is poured on a few handfuls of earth, and covered with paper; it takes fire, and burns with great heat, but diffuses a smoke in great abundance, which is noxious to all bodies that come in its way, and has a very disagreeable smell. Petroleum is likewise thought to be a part of the Greek fire. Thick petroleum makes a very solid and durable mortar. By the decoction of asphaltus with water, an oil is obtained, which is used for pitching vessels.

Finally, Some physicians have described petroleum as successful in disorders affecting the muscles, palsy, &c. by rubbing the skin with it, or exposing the patient to its smoke. Vanhelmont thought friction with petroleum, an excellent cure for frozen limbs, and recommends it as a good preservative against the effects of cold.

PART THIRD.

THE VEGETABLE KINGDOM.

CHAP. I.

Of the Structure of Vegetables.

VEGETABLES are organized beings, confined to the surface of the earth, without sensibility or power of motion. They are known by their appearance, and the conformation of their parts. They are distinguished from minerals, by receiving their nourishment internally, and elaborating the juices to which they owe their growth. They display to our observation phænomena which depend on their organization, and are called *functions*; the chief of these is that of reproducing themselves by seeds, or *ova*, like animals.

Vegetables differ from one another, 1. In size; they are divided into trees, shrubs, herbs, mosses, &c. 2. In local

local situation ; some grow in dry grounds, others thrive in a moist soil ; some, again, in sand, clay, water, on the surfaces of stones, or on other vegetables, &c. 3. In smell, taste, colour, &c. 4. In duration ; plants either live for a number of years, or only for one year, or are produced and die twice a-year, &c. 5. In the uses to which they are applicable ; they are used either as aliments, or as medicines. A great many of them are made use of in the arts, for dyeing, &c. others for adorning gardens, &c.

Vegetables, considered with respect to the external conformation of their parts, consist of six parts or organs, destined each to a peculiar function : these parts are the root, the stem, the leaf, the flower, the fruit, and the seed. These, again, differ in different plants, in form, contexture, bulk, number, colour, hardness, taste, &c.

1. The root is concealed in the ground, in water, or in the bark of some other vegetable. It is either tuberous, or fibrous, or bulbous. Its direction is either perpendicular or horizontal. Both its form and consistency are subject to great varieties. Botanists divide the roots of plants into many species ; which distinctions they sometimes make use of to determine the specific characters of the plants themselves,

2. The stem proceeds from the root, and supports the other parts of the plant. It is either solid or hollow, ligneous or herbaceous, round, square, triangular, or with two very acute angles, &c. The stem consists of wood and bark. The wood is distinguished into wood properly so called, and sap : the bark consists of the epidermis, the vesicular part or pulp, and the cor-

tical strata or inner rind. The stem divides into branches, the structure of which is precisely the same with its structure. This part, too, is liable to such diversities as enable botanists to establish upon it the distinctive characters of species, and still oftener of varieties.

3. The leaves of vegetables are extremely various: A. in form; they are oval, round, linear, sagittate, hastate, oblong, elliptical, cuneiform, &c.: B. in their position on the stem; they are sessile, petiolate, opposite, alternate, stellate, perfoliate, vaginal, &c.: C. in their margins; they are uniform, dentate, crenate, serrate, repand, undulated, laciniated, truncated: D. in simplicity or composition; compound leaves are formed by the insertion of foliolæ, or smaller leaves; they are then either digitate or conjugate, with either an even or an odd number of leaves: E. in place or situation; they are radical, cauline, or floral: F. in colour, smell, taste, consistency, &c.; they seem designed to absorb elastic fluids from the atmosphere, and to pour others into it, according to circumstances.

4. The flowers are those parts which Nature has designed to contain the organs of generation, and to preserve them from injury till the fecundation be accomplished; at which time they fall off. A flower consists of two parts; the exterior, designed to cover and protect the interior; the use of which is to re-produce the plant. The former comprehends the calix and the corolla; the calix is exterior, and of a green colour.

Linnæus divides the calices of plants into seven species; namely, the perianthium, the spatha or sheath, the husk, the involucre, the amentum or catkin, the calyptra

calyptra or veil, and the volva. The corolla is the coloured part, commonly called the *flower* : it is either a single piece, and monopetalous ; or consisting of several pieces, polypetalous. Tournefort's system is founded on the corolla. The pieces of the corolla are called *petals*. The organs inclosed, and often entirely concealed in the corolla, are the *stamina* and *pistils* or *styles*. The *stamina* are the male or fecundating parts ; and are almost always more numerous than the *pistils*. They consist of the filament and the *anthera*. The *anthera*, placed at the extremity of the filament, is a small bag, containing fecundating powder. The *pistil* stands in the middle of the *stamina* ; it is sometimes on another flower, or even on another plant : this circumstance has caused some plants to be distinguished into male and female. The *pistil* consists of three parts ; the inferior part, or *ovarium*, which contains the embryo, and is called in Latin *germen* ; the filament, which rises out of the *ovarium*, or *style* ; and its extremity, which is more or less dilated, and is called *stigma*. The sexual system of Linnæus is founded on the number, and the relative positions of the *stamina*, and the *pistils*. M. de Jussieu has formed a system from the insertion of the *stamina*, above or under the *germen*, &c.

5. Flowers are succeeded by fruits. Botanists distinguish fruits into seven species ; the capsule ; the filiqua ; the legumen ; the *consepimentum*, which becomes dry ; fruits having kernels ; fruits having pippins and berries, which remain succulent. The purpose of these organs is to inclose the seeds, and to protect them from suffering by the action of external bodies.

6. The seeds of plants differ greatly in form, magnitude, appendices, &c. The seed contains the plumula, or small plant, the radicle, and the cotyledons. There are two of these latter in most vegetables; yet many families of plants have but one cotyledon. This part is to the grain, what the yellow and white of an egg are to the embryo bird; it contains a substance intended for nutriment to the young plant during the germination. Besides, the cotyledons of many seeds contain fleshy and farinaceous bodies, &c.

Vegetables, considered as to their internal structure, contain five species of vessels, or organs, which exist through all their parts, 1. The common vessels which convey the sap. These are placed in the middle of plants and trees; they rise perpendicularly, but bend laterally, so as to form small vacancies between them. 2. The peculiar vessels which secrete and convey the juices peculiar to each vegetable, oils, resins, gums, &c. These are placed under the bark; they are often dilated into cavities, or reservoirs; they seem to be excretory ducts. 3. The tracheæ, through which the air that vegetables take in from the atmosphere, circulates. When a young and green branch is broken, these may be observed, and known from their spiral form, resembling a cork-screw. They are often full of sap. 4. The utricles, which are formed of small bags, containing the pith, and frequently colouring matter. They are placed in the middle of the stem. 5. The vesicular tissue, exhibiting a series of small cells, leading horizontally from the pith, crossing the sap-vessels, filling up the vacuities among them, and spreading over the epidermis, where they form

a soft covering like the skins of animals. The vesicular tissue of vegetables seems to correspond to the cellular membrane of animals.

All parts of vegetables consist of an assemblage of these five kinds of vessels ; which are, each of them, more or fewer in number, dilated, contracted, &c. On this diversity, in point of number and disposition, depend the differences in the form and texture of the roots, stems, leaves, &c. of plants.

Malpighi, Grew, and Duhamel, are the three naturalists who have studied the anatomy of vegetables with the greatest success ; and their works will be consulted with the greatest advantage, concerning the internal structure of the several parts of vegetable bodies.

C H A P.

C H A P. II.

Of the Natural Philosophy of Vegetables.

ALL these organs of vegetables, of which we have given the above brief account, are designed for the performance of the various motions called *functions*. These functions are,

1. The motion of the fluids, which is a sort of circulation.
2. The alterations or changes produced on those fluids, which are effected in their secretion.
3. The growth of the vegetable, and the developement of its parts by nutrition.
4. The exhalation of the several fluids elaborated by the organs of vegetables, and the receiving of several principles from the atmosphere by the same organs.
5. The action of air, and the employment of that fluid in the vessels of vegetables.
6. The motion performed by some of their parts.

7. That sort of sensibility by which they court the contact of bodies that may be useful to them, such as light, &c.

8. Lastly, The several phænomena, by which plants are generated, and species reproduced. Let us consider each of these functions more particularly.

The principal fluid in vegetables, which is called the *sap*, is contained in certain ducts, which are known by the name of *common vessels*. These vessels, situated in the centre of the stem, and under the bark, extend from the root all the way to the leaves and flowers. The sap which they convey is a colourless fluid, more or less insipid in taste, and intended, like the blood of animals, to be separated into different juices, for the nourishment and sustenance of the various organs. In spring it flows very copiously, causing the plant to display leaves and flowers. By applying ligatures, and by all the phænomena of vegetation, it has been proved, we think in a satisfactory manner, that the sap ascends from the root through the stem and the branches. We are not so certain whether it be true, as some naturalists have thought, that it descends again towards the root. The existence of those valves, which some botanists have represented as belonging to the common vessels of plants, has not been demonstrated; not at least unless we give the name to certain filaments or hairs with which Tournefort and Duhamel have observed their interior sides to be lined. There is a vast difference between this irregular motion and the circulation of the fluids in animals.

The sap being conveyed into the utricles, and thence into the proper vessels, is there elaborated in a peculiar manner. By this elaboration it is wrought into different fluids,

fluids, saccharine, oily, mucilaginous, which are discharged by an organic excretion; and of which the evacuation seems to be an advantage to the vegetable, as it does not appear to suffer even from a considerable loss of these matters. This alteration of the fluids, which may be distinctly observed as it takes place in several of the organs, in the nectarium, for instance, at the extremity of the pistil, in the pulp of fruits, at the base of the calices, and of many of the leaves, is entirely effected by a function similar to that which in animals bears the name of *secretion*. Guettard has carried this analogy so far as to describe glands of various forms, at the bases of the leaves of fruit-trees, and towards the inner extremity of the petals of certain flowers. This secretion separates the odorous principle, the colouring matter, the combustible substance, &c.; but it differs from animal secretion, as animal secretion is entirely owing to the organization of the glands which elaborate the animal fluids: whereas in vegetables, the juices conveyed through the common vessels, are in the proper vessels more exposed to the contact of air and light, and the action of heat; and their situation renders them liable to pass, by the operation of these agents, through a process of fermentation, by which only they can be altered.

The sap in the cavities of the utricles and the vesicular tissue, becomes thick, and acquires more or less consistency. In consequence of this alteration, it adheres to the sides of the fibres, and incorporates with them gradually, so as to increase their dimensions. Such is the mechanism by which vegetables are nourished and grow, and unfold their parts. It bears a great resemblance to
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the nutrition of animals. The vesicular tissue of vegetables, and the cellular membrane of animals, are formed with a similar structure, and intended to serve similar purposes. They pass in the same manner through all the organs of the bodies to which they respectively belong ; they establish a direct communication among these organs ; and both may be said to be the seats of nutrition.

Philosophical botanists have long been convinced, that plants exhale effluvia, from their surfaces, which are diffused through the air. The odorate spirit of leaves and flowers forms round vegetables, an atmosphere which affects the senses in a lively manner ; and which, as has been observed with regard to the fraxinella, the contact of a burning body will sometimes set on fire. This effluvia appears to be an inflammable gas of a peculiar nature. Mankind have also learned from fatal experience, that some vegetables exhale vapours, noxious to such animals as approach them. The walnut, the yew, and many other trees, natives of warm climates, are of this kind.

M. Ingenhoufsz has discovered by experiment, that the leaves of all plants, when exposed to the sun and to light, pour into the atmosphere an invisible fluid, which is vital air of the same qualities with that obtained from oxide of manganese, mercury, &c. But in the shade they no longer exert such a property ; instead of vital air, they give out carbonic acid gas, when deprived of the contact of light. This valuable discovery, which was first communicated to the world by Dr Priestley, shows vegetables to possess a property that was not before attributed to them, and to be capable of purifying
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and renovating the air, by pouring into it a portion of that vivifying fluid which is constantly consumed by combustion, respiration, &c. But if vegetables are continually diffusing vaporous fluids through the atmosphere, produced by the last processes of vegetation ; they likewise absorb several of the principles of the atmosphere. The experiments of Bonnet show, that the under surface of the leaves absorbs moisture from the dew. Dr Priestley has proved, by his researches, that vegetables absorb the gaseous residues of combustion and respiration ; for vegetation is more speedy and vigorous in air altered by these phenomena. Exhalation and inhalation are therefore much more considerable and important phenomena of the vegetable kingdom, than they were known to be before the modern discoveries. It even appears, that the water absorbed by the under part of the leaves is decomposed by their organs, its hydrogenous gas absorbed, and its oxigene converted into the vital air which is disengaged from the upper surfaces of the leaves. The rays of the sun contribute greatly to this decomposition ; for it does not take place in the shade. The water being then not decomposed, but absorbed entire, renders the plants white, insipid, soft, and in a word *atiolated* ; and in such cases, much less colouring, combustible, or oily matter, is formed, than when the plant is exposed to the action of light.

The gases absorbed by vegetables are conveyed through all their organs by vessels known under the name of *tracheæ*, which in their use and structure bear a resemblance to those of insects and worms. But the conveyance of this fluid is not the only purpose for which these *tracheæ* are intended. They are observed to be filled

illed with sap in the season when that fluid flows in greatest abundance ; a circumstance which distinguishes them widely from those organs of respiration which belong to so great a number of animals, and are so essentially necessary. From the theory of respiration which we have laid down in the history of air, it is easy to explain why vegetables possess not free heat in a degree of temperature superior to that of the atmosphere.

Several parts of vegetables have, no doubt, an internal principle of motion. In some plants this motion is so considerable as to be observable by the eye. Such is the motion of the sensitive plant, of the stamina of the Indian fig, of pellitory, &c. This motion seems to correspond to that function of animal organs which is called *irritability* ; for it is effected by the action of a stimulus, and by peculiar organs, which are by some botanists compared to the muscular fibres.

Can we deny plants to possess a sort of sensibility, when we see them turn their leaves and flowers towards the sun ; when we observe, that, if enclosed in boxes of wood, with glass on one side, or perforated with an open hole, or simply thinner on that side than on the other, they constantly turn towards the transparent body, or the aperture through which light is permitted to enter, or the side which, being thinner, is nearer to that fluid than the other ? Or, is this appearance of sensibility rather to be considered as an effect of the power of affinity, of the tendency of vegetables to combine with light ? It has been fully proved, that, either by percussion or combination, this substance produces in plants the properties of colour, taste, and combustibility ; in the shade, even the tallest plants are white, insipid, aqueous, and destitute

destitute of any inflammable principle : but, again, vegetables exposed to the rays of the sun, in the torrid climates of the south, are very high coloured, contain bitter and resinous parts, and are very combustible. However strong this affinity be allowed to be, yet it is hard to imagine how it could excite such a motion in the branches and leaves of vegetables. We must therefore grant them a peculiar sensation, a sort of feeling very different indeed from that of animals, by which they are enabled to distinguish and prefer such situations as are most exposed to the light.

The methods which nature uses for the reproduction of species of vegetables are strongly analogous to those by which the generations of animals are perpetuated. The greatest number of the species of plants are propagated by sexual coition. The labours of the celebrated Linnæus have discovered a striking resemblance between the organs designed for this purpose in these two classes of organic beings. The stamina of plants correspond to the genital parts of male animals, and the pistils consist of three parts, which bear an equal resemblance to the same organs of female animals. The embryo is developed by the action of the fecundating powder, without which a new individual could not be produced from it ; agreeably to what is daily observed of birds. But besides this analogy, which it would be needless to trace farther, as vegetables are of a much simpler structure than animals, and their parts consist all of the same organs, any of them is capable of producing a new individual similar to that which it belonged. This is the reason of the reproduction of plants by means of scions or slips, as

well as of the alteration of their fluids by grafting, whether natural or artificial. Here, therefore, is another analogy between vegetables and that class of animals which are reproduced by division into pieces, as polypi, crustaceous insects, certain worms, &c.

All these functions of vegetables, which bear so striking an analogy to those of animals, are liable to alterations, by which the vegetable is brought into a diseased state. These diseases to which plants are liable, depend commonly either on superfluity or defect of sap, as well as on the bad qualities which the sap may happen to acquire; and they bear, therefore, no small resemblance to those with which animals are affected. Their causes, symptoms, and cure, come under the general principles of medicine; and form a branch of agricultural knowledge, in which, it must be confessed, little progress has yet been made; but which may be greatly advanced by following the directions of some celebrated modern writers on the subject.

C H A P. III.

Of Juices and Extracts.

THE fluids contained in vegetables are of two kinds, the common and the proper juices. The first of these constitute the sap, which is found in all plants. This fluid seems to perform the same functions in vegetable, which the blood does in animal bodies. It is contained in the common vessels : It runs naturally from their surfaces ; but may be extracted in greater abundance by incision. The sap is not an aqueous fluid, but contains salts, extracts, and mucilages. When a certain quantity of it is wanted, in order to an examination of its properties, or for medical uses, the plant is brayed in a mortar, and squeezed through a linen cloth : if the plant do not readily yield its juice, it is put into a press.

Succulent vegetables give out their juice by simple expression. Those whose juices are viscid, or not very copious, must be treated with water to swell and dilute them ; such are borage and the dry aromatic plants.

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This fluid, when extracted by the force of pressure, is found to contain a portion of the solids of the vegetable, which were bruised with the pestil: it must then be purified. Juices of plants are purified, 1. Simply by rest, or by filtration, when they are very fluid: in this way, for instance, are the juices of purslain and the house-leek purified. 2. By the white of eggs, which collects the impure parts by coagulation; it is used with borage, nettles, &c. 3. By the simple application of heat, which coagulates and precipitates the parenchyma: M. Baumé recommends this as the best way for purifying those vegetable juices which contain volatile principles, such as that of cochlearia, cresses, &c. The phial containing the juice is immersed in boiling water, care having been taken to cover it with a piece of paper perforated with a hole; when the juice becomes pure, it is taken out; it is then immersed in cold water, and the juice filtrated. 4. By alcohol, which coagulates the feculent part. 5. By vegetable acids, which the London Pharmacopœia prescribes for the juices of cruciform plants.

There are matters dissolved in the juices of plants, which, when separated from the aqueous vehicle, form what is called in pharmacy the *extract*. These matters are distinguished into three species, mucilaginous, saponaceous, and gum-resinous extracts.

Those are called *mucilaginous extracts* which dissolve easily in water, are scarce soluble in alcohol, and undergo spirituous fermentation; such is the rob of the gooseberry, which is prepared by evaporating the juice.

Saponaceous extracts dissolve in water, and partly so-

luble in alcohol, and rather mould than pass into a state of spirituous fermentation. Such is the juice of borage when reduced to an extract. These are extracts properly so called.

Gum-resins are soluble both in water and in alcohol. They are inflammable, as containing a resinous principle, and are not liable to suffer any alteration from air. The concentrated juice of wild cucumber, called *elaterium*, is of this sort. Incisions are made in the fruit of this plant; and the juice squeezed out, suffered to clarify of itself, and evaporated to dryness on a water-bath.

These three different sorts of extracts are prepared in the great way for commerce, by the evaporation of the juice of various plants. Of these, among others, are,

1. The juice of acacia; which is prepared in Egypt by pounding the fruit of that tree, pressing out the juice, and evaporating it by the sun: the juice of acacia, from Germany, is prepared from the juice of flocs by a similar process.

2. That of hypocistis, which is prepared like the above, from the fruits of this parasitical plant.

3. Opium, a medicine of great importance, the nature of which should be very well known. It is extracted from the white poppy in Persia, &c. There flows out, by incisions made in the green capsules of that plant, a white juice, which is dried into brown tears; this is the true opium. The opium which is commonly sold, is prepared by first soaking the capsules in water, and then squeezing them; this juice is dried, and formed into flat circular cakes, covered with leaves, and
mixed

mixed with a good deal of impurities. To purify it, it is dissolved by the help of heat, with as small a quantity of water as possible; the liquor is filtrated or strained by strong pressure, and evaporated on a *balneum mariæ*. This is the extract of opium. This substance contains a saponaceous extract, a resin, a solid essential oil, an odorous principle, which is poisonous and narcotic, an essential salt, and a glutinous matter. As the odorous, poisonous, and narcotic principle, is often noxious, attempts have been made to obtain the extract of opium without that principle. M. Baumé, who has examined this medicine with much care, volatilized that principle, together with the essential oil, and in consequence of that, separated the resin by digestion, for six months. Bucquet has discovered, that this extract may be obtained in such a state as to be sedative, and not narcotic, by dissolving opium in cold water, and evaporating the solution in a *balneum mariæ*. Lorry, who has made some very valuable experiments on this matter, has discovered, that fermented opium affords by distillation a sedative water which has no poisonous qualities, and has prescribed it with great success. He observes, that the odorous principle of this medicine cannot be destroyed by this process.

To obtain the extracts of dry ligneous plants, we must employ maceration, infusion, or decoction in water, according to the particular state and nature of the matter, from which the extract is desired; maceration is often sufficient. Odorous plants can only be treated by infusion. Decoction carries off too much of their substance, and separates the resinous part: it forms an highly concentrated thick fluid, which becomes turbid

by cooling. Infusion will be sufficient in any case. Such is the opinion of the greatest chemists and the most celebrated physicians.

By water, various products can be extracted from several plants. Thus juniper-berries afford with water a mucilaginous extract; quinquina affords a saponaceous extract, which is obtained in small transparent scales, of a saline appearance, if the solution be evaporated in broad flat vessels; rhubarb affords in the same manner a gum-resinous substance.

The chemical extract, properly so called, or the saponaceous extract, was thought to be a compound of oil with fixed vegetable alkali. It was justly observed, however, that the extracts prepared in pharmacy are far from being all of the same nature; they are mixed with mucilage, essential salt, saccharine juice, and resin. For this reason, Rouelle, with a view to throw new light on this part of medical chemistry, has distinguished them, as above mentioned, into three genera. But the pure extract, reckoned among the immediate principles of vegetables, is to be considered as a compound differing from the others, and possessed of peculiar properties. I have just discovered, that this principle is not a soap; that it possesses the property of absorbing oxygen from the atmosphere; of becoming insoluble in water, and of assuming the characters of a concrete oil. These are the properties by which I ascertain the presence of this substance, and distinguish it from all the other immediate principles of vegetables.

There are extracts prepared in the great way for commerce by water. Such are,

1. The juice of liquorice, which is yellow by the first infusion, and black by a powerful decoction. The black juice is burnt, and actually contains coal. It is purified by melting it in water, filtering and evaporating the solution, which is rendered aromatic by the addition of essential oil, of anniseed, cinnamon, &c.

2. The cachou, which is obtained in the East Indies, from an infusion of the seed of a certain palm-tree, called the *areca*. This solution is evaporated, and the matter obtained is formed into broad cakes. The cachou is purified for medical purposes by solution in water and evaporation. It is seasoned with aromatics like liquorice-juice.

Among the extracts which are prepared for medical purposes, Rouelle has taken particular notice of those mixed with resin, by the name of *extracto-resinous*, or *resino-extractive matter*.

Extracto-resinous matter does not burn till after it be dried : it seems to contain more extract, properly so called, than resin. *Resino-extractive matter* burns much better than the former : it seems to contain a greater proportion of resin than of the extractive matter. This distinction proves these two species to be nothing but mixtures of extract in various proportions with a resinous principle. They are not, therefore, extracts properly so called ; and the name can be with propriety applied only to the saponaceous matter ; which is therefore the substance whose properties we ought to examine.

The pure extract differs from those above mentioned. Taking all its properties together, we may consider it

as a dry solid substance, of a brown red colour, transparent, not capable of burning by itself, but which exhales a good deal of smoke, and is found to contain more or less essential salt. Its taste is almost always bitter, it affords by distillation an insipid phlegm; exposed to a moderate fire, the phlegm by degrees takes a colour, and becomes of an alkaline nature, which is observed of elaterium, the extract of borage, &c. The ammoniac of the product, is formed by the heat: there passes next a little empyreumatic oil; the coal is light, contains potash, and almost always neutral salts. The extract, when exposed to the air, acquires a kind of moulding over its surface, and attracts moisture; and the salts mixed with it, crystallize and separate from the extractive part. They are often entirely altered and decomposed on this occasion. It dissolves in water, and is then like a strong infusion. Acids decompose this solution like soaps. Metallic solutions likewise precipitate it; and the substances are, on this occasion, mutually decomposed. These properties were thought sufficient to make extract be looked upon as a kind of soap: they are mostly owing, however, to the attraction of this substance for oxygen, and to its absorption of this principle. Extract, therefore, properly so called, must henceforth be considered as an organic compound of hydrogen, carbon, and a little azote, possessing a strong attraction for oxygen, which it absorbs from every substance that contains it, and afterwards passes into an oily concrete state.

Extracts are employed in medicine as aperitives, diffusives, diuretics, stomachics, and almost always with great success.

C H A P. IV.

Of the essential Salts of Vegetables ; and of those in particular which are analagous to Mineral Salts.

THE saline substances held in solution in the juices of plants, or in water in which they have been infused, are called their *essential salts*. They are extracted by suffering these fluids to cool, after they have been evaporated to the consistency of a syrup. As these salts are impregnated with extracts and fat matters, they need to be purified with lime and the white of eggs. When the salts are acid, lime must not be used, as it would neutralize them, but pure white clay in powder. After this first extraction, they are still very impure. They are dissolved in distilled water, and repeatedly crystallized till they become white. This process can be employed only on those essential salts of vegetables which are crystallizable ; but there have been some vegetable salts discovered which are not crystallizable, and which, on account of their mixture or combination with other principles, cannot be extracted by such a simple process. In giving an account of the salts contained
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vegetables, or at least obtained from them, we shall distinguish them into the following six genera.

The first genus comprehends all such vegetable salts as are analogous to those with which we are acquainted in the mineral kingdom.

The second consists of the pure acid salts of plants.

In the third we shall rank acid salts combined with a certain quantity of potash, under the generic name of *acidulæ*.

To the fourth genus we may refer such as are formed by the action of the nitric acid on some vegetable matter.

The fifth may contain such as owe their formation to heat.

Lastly, Under the sixth we include vegetable acids produced by a particular fermentation.

First Genus of Vegetable Salts. Salts analogous to those of the Mineral Kingdom.

THE first genus of the essential salts of vegetables comprehends neutral salts extracted from their juices by evaporation, which are analogous to those of the mineral kingdom. The principal species of these salts are,
 1. Fixed alkalis in combination with carbonic acid, which are obtained from almost all plants, by macerating them in acids, as has been shown by Margraff and Rouelle the younger : potash is most commonly obtained ; soda exists in some marine plants. 2. Sulphate of potash, in millefoil, in old borage, in astringent and aromatic plants, in spurge flax, and in the mark of clives. 3. Sulphate of soda, from tamarisk, and from
 rotten

rotten wood. 4. Nitre, from borage, turnsole, tobacco, &c. 5. Muriate of potash, and muriate of soda, from marine plants. 6. Sulphate of lime, discovered by Model in rhubarb. The existence of the last salt is doubtful; for Schæele suspects that what Model took for sulphate of lime was only calcareous oxalate.

By an accurate analysis of a greater number of plants, many other salts might no doubt be found in vegetables, resembling mineral salts. It was also thought that ammoniacal carbonate existed ready formed in some cruciform plants; because those plants, when distilled, afforded, by the first impression of the heat, a phlegm, in which there was a little of this salt dissolved. The ancient chemists, on this account, called those plants *animal plants*. But Rouelle the younger has shown, that the salt is not ready formed in the plant, but is produced in consequence of the re-action of the principles of the plant occasioned by heat. M. Baumé has represented this volatile principle of cruciform plants, as being nothing but sulphur. The ammoniac obtained from those plants has been fully proved by M. Berthollet, to proceed from the combination of the hydrogenous part of the oil with the azote contained in the vegetable.

Naturalists have been of different opinions concerning the mineral salts found in plants. Some think the salts to be conveyed from the earth into the vegetable by water, without alteration. Others think them to be formed by the act of vegetation. One thing certain is, that two very different plants, such as borage and millefoil, growing on the same soil, afford each its peculiar acid; borage, nitre, and millefoil, sulphate of potash. This doubtful

doubtful question might be determined by a single experiment ; of which much has been said, but which has never been performed with sufficient exactness. The experiment is, to raise, from a previously lixiviated earth, plants affording a kind of salt, like nitre, and to water them with water impregnated with muriate of soda, or some other salt. If they should be still found to afford nitre, and not muriate of soda, it might be inferred, that salt does not pass from the earth into the plant unaltered, but that the proper salt is formed in the plant by the functions of vegetation. Whatever may be the result of this experiment, it will be proved, that a number of the salts which we examined in the mineral kingdom are immediately formed in vegetables.

C H A P.

C H A P. V.

Of the second Genus of Essential Salts, or of the Pure Acids of Vegetables.

IN the second genus of essential vegetable salts, we rank those acids which are entirely formed in plants, and are extracted from them pure by very simple processes. There are five acids of this genus, the citric, the gallic, the malic, and the benzoic.

§ 1. *Of the Citric Acid.*

WE give the name of *citric acid* to the pure acid which Scheele obtained from lemon-juice.

Chemists formerly, without attending to the peculiar characteristic of this acid juice, compared it to that of tartar; and at that period all vegetable acids were thought to be of the same nature. Attempts have been made to concentrate and purify the acid juice of the lemon.

mon and the orange, in order to preserve them for long voyages. The juice of the former of these fruits has such an acid taste, and produces such an effectual alteration on blue colours, that there can be no doubt entertained concerning its nature. M. de Morveau has found the specific gravity of this juice to be to that of distilled water as 1,860 to 1.

When this juice is kept for some time, it acquires a disagreeable taste, and is covered over with a mouldiness: this alteration is owing to its containing a considerable proportion of mucilage, of which chemists have endeavoured to purify it. Before means were found out by which that might be accomplished, it was preserved in glass bottles, and covered with oil. Some people proposed to put sand into the vessels; others added a mineral acid; either of these processes altered the nature of the juice. The first was superior to the others; but even with it, the juice, in the space of a few days, contracted a tart, oily, and disagreeable taste. M. Georgius, in the year 1774, published, among the Acts of the Academy of Stockholm, a process for concentrating the acid juice of citrons, and rendering it unalterable. He directs this juice to be kept for some time in the cellar, in inverted bottles, in order to separate from it a part of the mucilage, and to expose it to a cold three or four degrees under oin Reaumur's thermometer; the aqueous part freezes, carrying with it, as would appear, a portion of the mucilaginous matter: care must be taken, as the ice forms, to separate the liquid from it; and the congelation must be carried on till the ice become acid. M. Georgius has found, that when the juice is reduced to an eighth part of its bulk, and is eight times as strong as before, a
I drachm

drachm of citron juice, concentrated by congelation, will saturate thirty-six grains of potash, which would require to saturate it an ounce of the same juice before concentration. This acid, thus concentrated, may be employed for many æconomical purposes. Dry lemonade is prepared by mixing it with sugar refined and reduced to powder, in the proportion of one part to six.

Citron, or lemon-juice, if exposed soon after its preparation to an atmosphere above the temperature of 15° of Reamur, deposits a white semi-transparent, mucilaginous matter, of a gelatinous consistency; this juice, when decanted and filtered, becomes less liable to alteration than before. The mucilaginous matter, when dried, does not dissolve in boiling water: when treated with the acid of nitre, it affords gas azote, and is converted into oxalic acid: this is not a gummy mucilage, but bears an analogy to the vegetable gluten, of which we spoke in the article *farina*.

M. Dubuiffon has preserved citron-juice by a process directly opposite to that of M. Georgius. On evaporating this juice by a moderate heat long continued, the mucilage becomes thick, and separates in the form of a crust and glutinous flakes; the acid liquid is concentrated, and may be long kept in well stopped bottles, without being liable to alteration. M. Dubuiffon has observed, that the contact of the air which remains between the stopper and the surface of this acid liquor concentrated by evaporation, is sufficient to separate in a few weeks flakes of a white substance, which he thinks to be glutinous, and which collecting on the surface, form there an elastic consistent body. The acid is not sensibly altered during this separation.

These

These are the several processes which were proposed and used, before Scheele's time, for purifying and preserving citron-juice. From them it appears, indeed, that this acid had engaged the attention of chemists; but it was prepared only for the purposes of pharmacy; and so fully was every one persuaded that its nature was the same with that of the acid of tartar, that no doubt was ever suggested of that being the case. Stahl had asserted, that lemon-juice, when saturated with the lobster-stone, or with chalk, acquired the nature of vinegar. Several chemists had attempted to combine it with alkalis, without obtaining permanent crystals from the combination, on account no doubt of the mucilage so plentifully mixed with it. M. de Morveau, however, informs us, that by saturating lemon-juice with carbonate of potash, exposing the solution to the air, and filtering it several times, he obtained from it a salt crystallized in small opaque grains not liable to deliquesce.

Scheele, in Crell's Journal, in the year 1784, gave a process for obtaining the acid of lemon very pure, separated from the mucilage and the extractive matter by which it is altered in the juice as pressed from the fruit, and in a concrete form. He first employed alcohol to separate the mucilage by coagulation, and did not succeed; the liquor, when inspissated, filtered, and evaporated, afforded no crystals. He tried the process which he had several years before discovered for purifying the acid of tartar, and obtained the acid of lemon, pure and concreted. The process is as follows: Saturate boiling lemon-juice with pulverized chalk. The acid forms with the lime a salt that is scarcely soluble, and the mucilaginous and extractive substances

substances remain dissolved in the supernatant liquor; the precipitate is to be washed with lukewarm water, till it cease to deepen in colour; it dissolves nearly as well as sulphate of lime: it is then treated with as much sulphuric acid as is requisite to saturate the chalk, diluted in ten parts of water; and the mixture is now boiled for a few minutes. Afterwards it must be cooled and filtered; the sulphate of lime remains on the filter; and the liquor affords, by evaporation, a concrete crystallized acid. In this operation, it is better, as Scheele has remarked, to use an excess of sulphuric acid, than to leave a little lime not saturated: as this would prevent the citric acid from crystallizing; whereas, when there is an excess of sulphuric acid, it remains in the mother-water.

The citric acid thus prepared is very pure and highly concentrated: its taste is strongly acid; it reddens all blue vegetable colours that are susceptible of such a change. Fire decomposes it, converting it into acidulous phlegm, gaseous carbonic acid, and carbonated hydrogenous gas: there remains in the retort a little coal: air effects no alteration on its crystals. It dissolves easily enough in water. The solution is decomposed by an actual putrefaction, which indeed takes place but very slowly. With earths and alkalis, it forms citrates of aluminous earth, barytes, magnesia, lime, potash, soda, and ammoniac; the properties of which have not yet been examined, though they are known to differ from all other neutral salts. The nitric acid does not convert this, like several other vegetable acids, into oxalic acid: this appears indeed to be one of the most powerful vegetable acids. It acts with the help of

water on various metallic substances, chiefly on zinc, iron, copper, &c.

Bergman has represented its affinities in the following order; lime, barytes, magnesia, potash, soda, ammoniac. M. de Breffey of Dijon has an account of its affinities somewhat different from this. According to him, barytes holds the first place, lime the second, and magnesia the third; the alkalis follow after these. It appears from the researches of both, that this acid prefers the three alkaline earths to the alkalis themselves.

The uses of the acid of lemon are various. With water and sugar, it composes a very pleasant drink, known by the name of *lemonade*. It is used in medicine as cooling, temperating, antiseptic, antiscorbutic, diuretic; it is especially efficacious in correcting the acridity of the bile. It is sometimes applied as a gentle escharotic to scorbutic ulcers, eruptions of the itch, and spots on the skin. When concentrated by the process of M. Georgius, or that of M. Dubuiffon, it may be put up for long voyages by sea; and it is found of great utility on such occasions.

§ II. *Of the Gallic Acid.*

WE give the name of *gallic acid* to that which is extracted from the nut-gall, which grows on oaks in consequence of the puncture of an insect. This acid is generally found, either in a greater or a smaller quantity, in all four or astringent vegetable substances: Such are oak, ash, willow, and the barks of these trees, quinquina, sumarouba,

simarouba, pomegranate, sumac, tormentillo, the cypress-nut, the stalk and leaves of the marsh iris, of the strawberry shrub, of the water-lily, &c.

Chemists formerly distinguished this matter by the name of the *astringent principle*: and all that they knew of it was, that it possessed exclusively the property by which its character was very distinctly marked, of producing black precipitates in solutions of iron in acids, and thus making ink. Messrs Macquer, Monnet, Lewis, Cartheuser, and Goanetti, sought to determine by experiments, in what manner this principle acts upon the metal. M. Monnet remarked, that nut-gall and astringent vegetable juices acted immediately on iron, and gave it a black colour. M. Gioannetti observed, that the atramentarious precipitate, or feculum, was not subject to the attraction of the magnet, and that iron therefore did not exist in the precipitate in a metallic state, as had been before thought. These observations might lead to the conclusion, that the astringent principle of nut-gall must be an acid, or at least performed the part of an acid in chemical operations. The Academicians of Dijon were, however, the first after these writers who distinguished, in their experiments, the astringent principle to be an acid. These philosophers have shown, 1. That the products of distilled nut-gall become black with the solution of sulphate of iron. 2. That an ounce of this substance communicates to cold water a tincture, from which $3\frac{1}{2}$ drachms of extract are obtained by evaporation. 3. That this infusion reddens turnsol and blue paper. 4. That the same principle is soluble in oils, alcohol, and æther. 5. That acids dissolve without altering it, and without depriving it of the property of

producing a black precipitate of iron. 6. That its solution in water precipitates alkaline sulphures. 7. That it entirely decomposes all solutions of metals, and communicates a colour to the oxides by combining with them. 8. Lastly, That it directly dissolves iron, and precipitates silver and gold, after separating them from their solvents.

Such are the important facts concerning this substance, which have been communicated to the world by the Academicians of Dijon. Several of them had indeed been before observed by different chemists, but none had before ascertained the acidity of the principle.

Since they communicated these observations to the world, Scheele has not only observed, that all four, astringent plants exhibit marks of acidity, but has discovered and described a process for obtaining this vegetable acid pure and crystallized.

Upon a pound of nut-gall in powder, pour six pounds of distilled water; leave this mixture to macerate for the space of fifteen days, in the temperature of from 16 to 20 degrees; then filtrate the liquor, and put it in a stone pot, or a large capsule of glass; suffer it to evaporate slowly in the air; a mouldiness, and a thick and seemingly glutinous pellicle is then formed upon it: mucilaginous flakes are first precipitated in great abundance; the solution has no longer a very astringent taste, but is more sensibly acid than before. After it has been two or three months exposed to the air, there is observed on the sides of the vessels, and adhering to them, a brown plate, covered with granulated crystals, sparkling, and of a yellowish grey colour: the same
crystals

crystals exist likewise in great abundance on the under side of the thick pellicle which covers the liquor: the liquor must now be decanted off; and hot alcohol is poured on the flaky sediment, the pellicle, and the crystalline crust: this solvent takes up all the crystallized salt, but affects not the mucilage. This spirituous solution is then evaporated, and the gallic acid is obtained from it pure, in small granulated crystals, of a grey colour, inclining a little to yellow, and brilliant.

The gallic acid thus purified has a taste somewhat sour and astringent. It produces in solutions of sulphate, and of other salts, of iron, a very fine and brilliant black precipitate: it gives a high red colour to the tincture of turnsol; when heated in contact with air, it swells and kindles, diffusing an agreeable enough smell, and leaves a coal, the incineration of which is very difficult: when distilled by a moderate fire, a part of it is dissolved in the water of its crystals, and ascends in that state; another part is sublimed, without being decomposed in small silky crystals; a strong fire separates from it some drops of oil, carbonic acid gas, and carbonated hydrogenous gas. Nut-gall, when distilled entire, affords a small portion of concrete salt, resembling the sublimated gallic acid.

The gallic acid requires 24 parts of cold water to dissolve it; of boiling water only three parts. Repeated solution and crystallization do not whiten it in a sensible manner. Alcohol dissolves it much more efficaciously: four parts of this liquid, when cold, are sufficient to dissolve one of gallic acid; when boiling, it dissolves a quantity of the acid equal to itself in weight.

This acid disengages the carbonic acid from earthy and alkaline bases, when its action is assisted by heat.

With barytes, magnesia, and lime, it forms salts soluble in water, and especially when there is an excess of the base. Potash, soda, and ammoniac, combine very readily with it, forming *gallates*, the properties of which are hitherto unknown. The nitric converts the gallic into oxalic acid.

The gallic acid precipitates gold in a brown powder, and causes a part of the metal to appear on the surface of its solution in a brilliant metallic pellicle. In the solution of silver it produces a brown precipitate; and soon after the precipitation, a plate of reduced silver appears on the surface of the liquor. From mercury it produces an orange yellow precipitate; from copper a brown precipitate; from iron a beautiful glistering black precipitate; from bismuth a citron yellow precipitate. Solutions of platina, zinc, tin, cobalt, and manganese, suffer no alteration from this acid.

Such are the properties which Scheele allows to the gallic acid prepared by his process. They are sufficient to entitle it to the character of a peculiar acid, distinct from all others. Its intimate nature, and the proportion of its principles, have not yet been ascertained. M. de Morveau obtained from it a resin which he thinks to be the acidifiable base; by the union of which with oxygen the acid is formed.

The use of nut-gall for dyeing black is well enough known: we shall only add to what we have already said of it in the article of iron, that when the pure gallic
lic

lic acid is used in the preparation of ink, the ink is very beautiful, and very black, and remains long unaltered.

§ III. *Of the Malic Acid, or the Acid of Apples.*

WE give the name of *malic acid* to a peculiar vegetable acid which Scheele extracted from the juice of various fruits, and of which he found apples to contain a considerable quantity.

This acid is obtained by squeezing the juice from four apples, saturating it with potash, and mixing the liquor with a solution of acetite, or sugar of lead. A double decomposition is thus effected; the acetous acid combines with the potash, and the malic with the oxide of lead; the malate of lead is precipitated; that precipitate is washed; and, on its being treated with sulphuric acid, sulphate of lead is produced, and the malic acid swims above. A sufficient quantity of sulphuric acid must be poured in to dissolve all the malate of lead; which, when it takes place, will be known from the taste of the supernatant liquor.

The following are the properties of this acid. It cannot be obtained in a concrete form; with the three alkalis, it forms deliquescent neutral salts; with lime, it produces a salt that affords small irregular crystals, soluble in boiling water, in vinegar, and in the malic acid itself; with aluminous earth, a salt that is scarce soluble; with magnesia, a deliquescent salt. It dissolves iron, and the solution is brown, and not susceptible of crystallization; it dissolves zinc readily, and produces with it

a salt in very beautiful crystals : the nitric acid changes it into oxalic acid ; it precipitates nitrate of mercury, lead, silver, and gold, in a metallic state : calcareous malate decomposes ammoniacal citrate, forming, in consequence of the decomposition calcareous citrate, not soluble in boiling water or in vegetable acids. The solution of calcareous malate in water is precipitated by alcohol ; lastly, The malic acid is speedily destroyed by fire, which changes it into carbonic acid : the carbonic acid, thus formed, saturates in part the bases of the malates decomposed by heat. Such are the properties which form the peculiar character of this acid.

Scheele found it almost pure, or mixed with a little citric acid, in the juice of apples, of the barberry, of alder twigs, of the floe-thorn, of the forb-tree, and of the plum-tree ; in gooseberries, cherries, strawberries, raspberries, &c. Lastly, He obtained it from sugar by the nitric acid ; and M. de Morveau remarks, that the malic acid shows itself in this case before the oxalic.

When four fruits contain both citric and malic acid, the following is Scheele's process for separating them, in order to obtain the latter pure. The juice of gooseberries saturated with chalk, affords calcareous citrate, which, being insoluble, is precipitated ; the supernatant liquor holds in solution the calcareous malate, which is separated by alcohol ; but as it is still in union with a mucilage, Scheele has had recourse to another means for obtaining it pure. He evaporated the juice of gooseberries to the consistency of syrup ; upon this syrup he poured alcohol, which dissolved the acids without affecting the mucilage ; he then filtrated the solution to separate the mucilage ; after the filtration of the liquor, he
evaporated

he evaporated the alcohol; the acids he saturated with chalk. The citric acid uniting with the chalk, was of consequence deposited in calcareous citrate; and the calcareous malate remained in solution. A new addition of alcohol precipitated it from the liquor; and Scheele then obtained the malic acid by dissolving this salt in water, precipitating the solution by acetite of lead, and decomposing the malate of lead by the sulphuric acid; the malic acid was then found separate in the supernatant liquor.

§ IV. *Of the Benzoic Acid, or the Acid of Benzoin.*

SINCE the days of Blaise de Vigenere, who wrote in the beginning of the last century, benzoin has been known to afford, by distillation, an acid salt crystallized in strong smelling needles, of an acrid taste, which in pharmacy are called *flowers of benzoin*. Chemists formerly thought this to be a particular modification of a mineral acid; but its distinctive properties are now so well known, that we can no longer doubt of its being a peculiar vegetable acid.

This acid is found to exist in benzoin, balm of Peru and Tolu, storax, liquidambar, and vanilla, around which it is crystallized. Scheele has found it likewise in the sugar of milk and the extract of urine. It will be shown under the article of *benzoin*, that the simple process which was formerly employed to obtain it, consisted in sublimation by a moderate fire. Geoffroy discovered, in the year 1738, that it might be extracted by water, and that the saline substance was fully formed as it existed in benzoin; by the same process, I extracted it from
Peruvian

Peruvian balm, storax, and the husks of vanilla. But this process affords only a small quantity ; for the resin of benzoin, not mixing with the water, covers and preserves a great part of the acid salt.

Scheele, in the year 1776, gave, in the Memoirs of Stockholm, some important observations on the benzoic acid : from ninety-six parts of benzoin he obtained, by sublimation, between nine and ten parts of this sublimated salt which was very far from what Spielman asserted that he obtained,—namely, a fourth part of the benzoin submitted to distillation : it appears that the chemist of Strasburg had taken acid of benzoin mixed with empyreumatic oil for pure acid. Scheele, having reduced benzoin to powder and mixed it with chalk, boiled upon it a quantity of water, and then filtered the liquor, which afforded no salt by cooling : sulphuric acid, poured into this liquor, separated the benzoic acid in powder, and showed that acid to have been united with a base of chalk, with which it formed a neutral salt soluble in water : the quantity of concrete acid, however, precipitated by this process, was not more considerable than that which is obtained by simple lixiviation. Scheele thought that a greater quantity might be obtained by employing a matter capable of acting on the resin, and facilitating the separation of the salt. Potash did not serve his purpose ; the resin again collected on the surface of the liquor in a thick tenacious oil, on which account he could not expect the acid to be entirely separated. With quicklime he was more successful. According to him it is to be applied in the following manner : Take four ounces of quicklime ; flake it with twelve ounces of water ; add eight pounds more when the ebullition ceases ;
mix

mix six ounces of this water with a pound of benzoin in powder ; these substances need to be well stirred, in order that they may mix properly ; pour in by degrees the remaining part of the lime-water ; when the lime-water is thus gradually poured in, it hinders the benzoin from collecting into a mass : this liquor must next be heated for half an hour by a moderate fire, and constantly stirred : it is then taken off the fire, and suffered to settle for several hours together : the clarified liquor is now decanted off ; eight pounds of water are poured upon the residue ; it is boiled for half an hour, and then mixed with the clarified liquor before poured off from it ; the operation is finished by putting the residue upon a filter, and pouring hot water upon it. These *lixivia* are next reduced all to two pounds by evaporation ; a little resin is separated : when the evaporated liquor is cooled, a quantity of muriatic acid is dropped upon it, till it cease to produce a precipitate, and the liquor take a discernible acid taste : the salt of benzoin is then precipitated in powder. It is to be edulcorated on the filter ; when it is wanted in crystals, it is dissolved in five or six times its weight of boiling water ; it is then filtrated through a cloth, and the solution slowly cooled ; the salt is deposited in oblong compressed prisms. In this process the lime absorbs the benzoic acid, and forms with it calcareous benzoate, which is very soluble ; and the resin is separated from that salt, which has but very little affinity with it. The muriatic acid which attracts lime with more force than the benzoic acid, seizes that earth, and separates the vegetable acid. The liquor, when reduced to two pounds by evaporation, is no longer sufficient to maintain the acid in solution, and

it is therefore almost all deposited. Calcareous benzoate has not the smell of benzoin; but as soon as the benzoin is separated by the muriatic acid, it takes that lively smell which is peculiar to this balsamic substance. By this process Scheele obtained twelve or fourteen drachms of benzioc acid from the pound of benzion; whereas sublimation affords only nine or ten. He farther informs us, that the purification of this salt by hot water and by crystallization, causes a great quantity of it to be lost, and is by no means necessary to prepare it for pharmaceutical purposes. In fact, this salt, when properly crystallized, is very difficult to be reduced to powder; and the design of the purification is to separate only about two grains of resin from the pound of benzoin. Lastly, He remarks, that the filtration of this acid, dissolved in water, can be effected only through a linen cloth. The salt being separated quickly, as the liquor cools, stops up the pores of paper, so that the filtration cannot take place.

Since these experiments of Scheele's were made known to the world, M. Lichtenstein has published in Germany some observations on the benzoic acid; in which he asserts, that sublimation affords more of this acid than the process by lime-water; but I agree with Scheele and Morveau, in thinking that this can be said only of the purified acid.

The purified benzoic acid has a taste somewhat sour, pungent, hot, and acrid; its smell is only a little aromatic; it communicates an high red colour to the tincture of turnsol.

Heat, while it volatilizes this acid, increases its smell amazingly. When exposed in a silver ladle to the heat
produced

produced by the blow-pipe, it becomes liquid, as has been observed by M. Lichtenstein, and evaporates without inflammation. When suffered to cool, it forms a solid crust, which exhibits on its surface some marks of crystallization in divergent radii. It does not burn with flame, unless when in contact with bodies that are burning with a strong flame. Burning coal only sublimates it rapidly.

Air appears to have no power of acting on this acid ; for after being preserved twenty years in a glass-vessel, a quantity of it was still very pure, and had lost nothing of its weight : it loses its smell indeed ; but that it regains by heat.

The benzoic acid is scarce soluble in cold water. It appears from the experiments of Messrs Wenzel and Lichtenstein, that 400 grains of cold water dissolve no more than one grain of this acid ; but the same quantity of boiling water dissolves twenty grains of it ; nineteen of which are separated by cooling. Bergman says, that boiling water dissolves one twenty-fourth of its own weight, and that water of a moderate temperature dissolves scarcely one five-hundredth part.

The benzoic acid combines with all earthy and alkaline bases, forming with them benzoates of aluminous earth, barytes, magnesia, lime, potash, soda, and ammoniac. We know not the particular characteristic properties of each of these combinations, nor the different affinities of the acid with each of these bases. M. Lichtenstein asserts, that it prefers the fixed alkalis, and even ammoniac, to aluminous, magnesian, or calcareous earth ; but a great many more experiments are necessary to determine exactly the order of these aff

ties : And these are the more necessary, because Bergman has given a different account of them. According to him, lime separates the alkaline bases, and barytes separates lime : it disengages carbonic acid from all of these bases.

The concentrated sulphuric acid dissolves it easily without either noise or heat, according to the same chemist ; but passes, in consequence of effecting this solution, into the state of sulphureous acid ; the benzoic acid may be separated from it unaltered by water.

The nitric acid likewise dissolves it, and gives it up in the same manner to water without alteration. M. de Morveau has caused these two bodies to re-act on each other with additional force by the application of heat. The nitrous gas was not disengaged till the end of the operation ; and the benzoic acid was separated without loss, and without alteration. M. Hermstadt, however, says, that when the concentrated nitrous acid is employed, the benzoic acid becomes fluid, and more fixed in its nature, and assumes the characteristics of the tartareous or oxalic acid : but new researches are necessary to establish the truth of this result, to which little confidence can at present be given. That which appears to be most certain concerning this acid is, that it differs in its nature and properties from all other vegetable acids, and retains in it an essential oil, to which it owes its smell, volatility, combustibility, and solubility, in alcohol.

CHAP VI.

Of Vegetable Acids, partly saturated with Potash, and of the same Acids pure.

IN the fourth chapter, we mentioned a particular class of vegetable acids; which, we said, were in part combined with potash. We know of two acids of this character, the acid of tartar, and the acid of sorrel. We call these acids which are partly neutralized, *acidulæ*; the one is the tartareous, the other the oxalic.

§ I. Of the Tartareous Acidula, or Tartar, and of the pure Tartareous Acid.

THE tartar sold in the shops is an essential acid salt, combined with a portion of potash and of oil, which is deposited on the sides of hogsheds containing wine, during the insensible fermentation of the wine. It is not, as some chemists have thought, a product of vin fer.

mentation; for Rouelle the younger has found it fully formed in muſt and in verjuice. Many other chemiſts have ſince found it fully formed in various fruits.

It is in the form of irregular plates arranged in ſtrata, often full of brilliant cryſtals, and of an acid vinous taſte. It is diſtinguiſhed into white and red tartar; the latter of which differs from the former only in containing a greater quantity of colouring extractive matter.

Crude tartar, when expoſed to fire in cloſe veſſels, affords a reddiſh acid phlegm, an oil that is at firſt light, but afterwards ponderous, coloured, and empyreumatic, a little ammoniac, and a great quantity of carbonic acid, which Hales, Boerhaave, and many other chemiſts have taken for air. There remains a coal which contains a good deal of carbonate of poſaſh, and is eaſily incinerated. By the combuſtion and incineration of tartar, fixed alkali is obtained in a ſtate of conſiderable purity. For this end, the tartar reduced to powder is put into rolls of paper ſteeped in water; they are then put into a furnace between two layers of coal; the coal is kindled, and the tartar is then burnt and calcined: when the fire is extinguiſhed, the rolls are taken out, and are found to retain their form; the matter which they contain is lixiviated with cold diſtilled water: This lixivium is filtered, and evaporated to a pellicle; it is ſuffered to cool, in order to ſeparate from it the ſulphate of poſaſh, which is formed by reſt; the water is decanted from above this ſalt, and it is evaporated and cryſtallized anew, till it ceaſe to yield ſulphate of poſaſh; it is then evaporated to dryneſs, and by this means affords
I
poſaſh,

potash, partly caustic, and partly combined with carbonic acid.

It is very difficult to dissolve tartar in water; for an ounce of water, 10 degrees above the freezing point, dissolves only four grains of tartar. As it contains a good deal of oily colouring matter, it is purified by solution and crystallization at Aniaen and Calvisson, in the neighbourhood of Montpellier. Doctor Fizes favoured the public with an account of this purification, in a Memoir printed among the Memoirs of the Academy for the year 1725.

The tartar is boiled in water; the boiling solution is filtrated; as it cools it becomes turbid, and deposits irregular crystals, which form a paste. This paste is boiled in copper vessels with water, in which there is a mixture of clayey earth, which comes from the village of Merviel, two leagues distant from Montpellier. A froth gathers on the surface of the liquor, which is carefully skimmed off, and is succeeded by a saline pellicle. The fire is then abated; and the pellicle being broken, mixes with the crystals which are precipitated from the solution: these crystals are washed with water, to purify them entirely from a mixture of earth, with which they are contaminated, and sold under the name of *cream* or *crystals of tartar*; the only difference between the cream and the crystals being, that the cream is crystallized on the surface, whereas the crystals are deposited at the bottom of the liquor. The white clay appears to serve the purpose of separating from the tartar the superfluous oily and extractive matter which it contains.

At Venice, tartar is purified in a way somewhat different from this, according to M. Desmaret's account. The salt is reduced to powder, and dissolved in boiling water; it is suffered to deposit any impure matter which it contains; and these are carefully taken out: the liquor then affords crystals by rest and cooling. These crystals are again dissolved in water, which is exposed to a gentle heat: when this new solution is heated to ebullition, beaten whites of eggs and ashes, previously passed through a sieve, are put into it. This mixture of ashes is repeated 14 or 15 times; the scum produced by the effervescence of the liquor is taken off; and it is then suffered to settle. A pretty white pellicle, and saline crystals of the same colour, are soon formed: the water is then decanted off, and the salt dried. By this method the nature of the tartareous acidulum is in some degree altered, and a part of it is changed into tartarite of potash. The cream of tartar, or purified tartar of Montpellier, must be the subject of our examination, in order that we may understand the nature of the pure tartareous *acidulum*.

The tartareous acidulum, when very pure, is crystallized, but in an irregular manner. Its taste is sour, and not so vinous as that of crude tartar. When it is put on a burning coal, it diffuses a good deal of smoke of a pungent empyreumatic smell; and becomes black and carbonaceous. When this substance is submitted to distillation in an earthen retort, with a balloon terminating in a tube, entering a bell-glass full of water, it affords, if the fire be gradually applied to it, a phlegm which is at first a little coloured, and somewhat acid: there

there passes after this an acid which is stronger and of a deeper colour ; an oil which by degrees acquires colour and consistency, and has an empyreumatic smell ; ammoniacal carbonate ; and a large quantity of carbonic acid. In the retort, there remains a good deal of coal, which, when lixiviated without incineration, affords a large proportion of potash. All of these products may be rectified by a new distillation at a moderate fire. The phlegm passes almost colourless ; the oil, by this rectification, becomes very white and volatile ; the ammoniac is in part combined with the acid, and can only be obtained separate and pure by distilling the last portions of the phlegm with an addition of potash. With respect to the coal, the potash which it contains is not produced in the course of the operation, as has been thought by some chemists not well acquainted with the nature of *cream of tartar* ; but exists in it ready formed before the operation. The production of the ammoniac is owing to the re-action of this alkali on the oil. A still greater quantity of the volatile salt may be obtained by distilling the oil obtained from the tartareous acidulum upon the coal which it leaves, when analysed in the retort. The proximate cause of the formation of the ammoniac is the combination of the azote of the potash with the hydrogen disengaged from the oil.

The tartareous acidulum suffers no alteration from air. It dissolves in twenty-eight parts of boiling water, and crystallizes by cooling, but in a very confused manner. There is a certain quantity of earth separated from the solution of this salt, which, no doubt, is a part of the earth that was employed to purify it. This so-

lution reddens the tincture of turnsol, and has an acid taste. When left exposed to the air, it becomes turbid, and, after some time, deposits mucilaginous flakes: the acid is then decomposed, and the liquor is, after this, found to contain nothing but carbonate of potash. M. de Machy was the first who observed this decomposition. Messrs Spielman and Corvinus likewise attended to it; but M. Berthollet has observed it with still greater accuracy than any former philosopher. He has observed, that two ounces of tartareous acidulum require eighteen months before they can be entirely decomposed; that these two ounces will afford, in that time, six and a half drachms of carbonate of potash, still oily, and mixed with a small quantity of carbonaceous matter; and that, therefore, the quantity of alkali obtained by this means from the tartareous acidulum is precisely the same which it would afford by combustion and calcination. The alkaline residue which remains after the distillation of this acidulum, and this spontaneous decomposition, prove, therefore, that it contains a proportion of potash, nearly equal to one-fourth of its weight.

We know nothing of the action of siliceous, and very little of the action of aluminous earth, and barytes on the tartareous acidulum. The chemists of the Academy of Dijon have observed, that magnesia forms with this acidulum a soluble salt, liable to be decomposed by fixed alkali; the solution of which affords, by evaporation in the open air, small prismatic radiated crystals. When exposed to fire, this tartarited magnesia emits bubbles, and is converted into a light coal. M. Poulletier de la Salle obtained from this combination, a gelatinous mass,
perfectly

perfectly like a mucilage. These phænomena depend on the particular state of the tartareous acidulum, which is in part saturated in this acidulated vegetable acid.

A number of chemists have given very good descriptions of the manner in which lime and chalk affect the tartareous acidulum. When chalk is cast into a solution of this acidulum, an effervescence takes place, owing to the disengagement of the carbonic acid, and a very copious precipitate is formed; the precipitate is a combination of lime with the tartareous acidulum. The supernatant liquor contains a neutral salt ready formed in the acidulum, or *cream of tartar*, which consists of the pure acid in union with potash: This salt, as we will hereafter see, has been improperly called *soluble tartar*. We are indebted to Rouelle the younger for this analysis of the tartareous acidulum by chalk. It proves, 1. That this substance consists of an excess of oily acid, and a certain quantity of the same acid, united with potash in the state of a neutral salt. 2. That the combination of the tartareous acid with lime, forms a neutral salt, which is scarcely soluble. M. Proust has discovered, that calcareous tartarite, distilled in a retort, leaves a residue that takes fire in the air like the pyrophorus.

The tartareous acidulum very readily combines with the different alkalis. Put into a solution of carbonate of potash a quantity of tartareous acidulum in powder; a lively effervescence is produced by the disengagement of the carbonic acid: let acidulum be added till the alkali be saturated; after boiling this liquor for half an hour, filtrate it, evaporate the filtrated liquor to a pel-

licle, and suffer it to cool slowly; oblong square crystals, terminating slopewise at two of their extremities, will be formed. This salt has been called *vegetable salt, soluble tartar, tartarized tartar*; but it ought to be called *tartarite of potash*. Its taste is bitter; when exposed to a strong heat, it becomes carbonaceous: it may be decomposed in a retort; and it then affords an acid phlegm, oil, a good deal of carbonic acid, and a little ammoniacal carbonate. It attracts, in some degree, the moisture of the atmosphere. It dissolves in four parts of water heated to the temperature of 40°. This solution is decomposed of itself in a few months; and it then leaves tartareous acidulum in combination with carbonic acid. The mineral acids decompose it, and precipitate the tartareous acidulum. It is also decomposed by most metallic solutions.

The tartareous acidulum, combined with soda, forms the *salt of Seignette*, who was an apothecary of Rochelle, and the first that made up this combination; we give it the name of *tartarite of soda*. To prepare it, put 20 ounces of the acidulum of tartar into four pounds of boiling water; add by degrees very pure crystallized carbonate of soda, till the acidulum be saturated; that is, till the addition of the alkaline salt no longer produce any effervescence. This combination renders the tartareous acidulum soluble. Evaporate the liquor almost to the consistency of syrup; and you then obtain from it, by cooling, very beautiful and regular crystals, often of a considerable size. These are prisms with six, eight, or ten, unequal sides, with their extremities truncated at right angles. These prisms are generally divided longitudinally into two; and the base on which they

they stand is marked with two diagonal lines, which cross each other so as to divide it into four triangles. Tartarite of soda, which was at first sold as a secret, and which was discovered at the same time by both Boulduc and Geoffroy in the year 1731, has a bitter taste. It is decomposable by fire, like tartarite of potash; it effloresces in the air, on account of its containing a good deal of water in its crystals: it is almost as soluble as tartarite of potash; and is, like it, decomposable by air, by mineral acids, and by metallic solutions. The mother-water of this salt contains that portion of tartarite of potash which entered into the composition of the tartareous acidulum.

Ammoniac forms with the acidulum of tartar an ammoniacal tartarite, which crystallizes very well by evaporation and cooling. Bucquet says, that its crystals are rhomboidal pyramids. Macquer saw some of them in large prisms, of four, five, or six sides; others swelled in the middle, and terminating in very acute points; and the Academicians of Dijon obtained this salt in parallelopipeds, with two alternate sloping sides. This salt, ammoniacal tartarite, has a fresh taste, and is decomposable by fire: it effloresces in the air; it is more soluble in hot than in cold water; and it crystallizes by cooling: lime and the fixed alkalis disengage the ammoniac; the contact of air, mineral acids, and metallic solutions, decompose it. It appears, that when this salt is prepared, the tartarite of potash, which, in union with the tartareous acid, constituted the acidulum, or *cream of tartar*, remains in the mother-water.

Pott and Margraff have treated the tartareous acidulum with mineral acids; and the latter obtained neutral

salts, the same with those which the same acids form with potash : from which he has inferred, that potash exists ready formed in the acidulum. Rouelle the younger, who prosecuted a similar train of experiments, obtained the same results. On throwing a pound of concentrated sulphuric acid on an equal weight of tartareous acidulum in a very fine powder, the mixture becomes hot ; the reciprocal action of the two substances may be promoted by the heat of a *balneum marie*, and by stirring them with a spatula of glass : let the heat be continued for ten or twelve hours ; the mixture will then become thick like a jelly : then pour upon it two or three ounces of boiling distilled water, to render it fluid ; and leave it on the *balneum-marie* for about two hours ; then take off the fire, and add three pints of boiling distilled water : the solution is now coloured and opaque ; it contains naked sulphuric acid, a portion of tartareous acidulum, not decomposed, and sulphate of potash. Saturate the excess of sulphuric acid with chalk ; a precipitate of sulphate of lime, with a small portion of tartareous acidulum, is then produced : filtrate the mixture, and evaporate the filtrated liquor ; it now affords so much tartareous acidulum and sulphate of lime, that it is reduced to eighteen or twenty ounces. It is next decanted and evaporated anew ; and it affords, by rest, crystals of sulphate of potash ; which may be thus obtained by repeated evaporation and crystallization, till the whole solution be exhausted. This salt is always mixed with a little of the tartareous acidulum, and it burns upon red iron ; but when lixiviated with a sufficient quantity of distilled water, it is dissolved, and the acidulum remains on the bottom of the vessel.

This process has been described, and successfully repeated, by M. Bemiard, after Rouelle.

The nitric and the muriatic acids, when treated in the same manner with the tartareous acidulum, afford nitrate and muriate of potash; which proves incontrovertibly the existence of potash in that substance.

The tartareous acidulum acquires solubility by union with borax and the boracic acid. According to the experiments of M. de Laffone, one part of the latter salt will render four parts of the tartareous acidulum soluble. This mixed solution affords, by evaporation, a greenish gummy salt, which is very acid. Common borax, when added to the tartareous acidulum, converts a part of the acid into tartarite of soda, in consequence of the soda which it contains.

The tartareous acidulum appears to be capable of uniting, without decomposition, with most metallic substances; as has been shown by M. Monnet, and the chemists of the Academy of Dijon. But as all of these combinations have been but very little examined, we shall here speak only of those in which the acidulum is combined with antimony, mercury, lead, and iron; because these compounds are better known, and are most employed in medicine.

The combination of the tartareous acidulum with antimony bears the name of *stibiatus*, or *antimoniatus tartar*. It consists of tartarite of antimony and potash. As it is one of the most valuable medicines which chemistry can supply, we must examine its properties with care. Since the time of Adrian, who first made it known to the world in the year 1631, the method of preparing it

it has been much varied. All the pharmacopœia, as well as the works of chemists, differ, either in respect to the antimonial substances to be employed in this preparation, or in respect to the proportions in which these, the water, and the tartareous acidulum, are to be mixed; or, lastly, in respect to the process by which these substances are to be united in stibiated tartar. In Bergman's Dissertation on this medicine, there is an excellent table of the various processes which have been given for the preparation of tartarite of antimony. The sublimated vitreous white oxide, the brown, and the orange-coloured oxides of antimony, have been successively recommended for this purpose. Some have directed to boil these substances with the tartareous acidulum, and a greater or a less proportion of water, for ten or twelve hours; others think half an hour's boiling sufficient: lastly, some writers prefer the evaporation of the filtrated lixivium to dryness; while others would have it to be crystallized, and only the crystals used in medicine. From these various modes of preparation, it happens, that tartarite of antimony can scarce ever be purchased twice precisely of the same strength and nature; and its effects can never be depended upon. Geoffroy, who had examined several sorts of *stibiated tartar* of different degrees of strength, found by analysis, that the weakest *stibiated tartar* contains in the ounce from thirty grains to a dram and eighteen grains of oxide of antimony: that which is moderately emetic, a dram and a half; and that which acts with most energy, no less than two drams and ten grains. The vitreous oxide of antimony

mony has been preferred to other antimonial substances for this preparation ; because it dissolves easily by the acidulum of tartar : but this metallic glass may happen to be more or less oxidated : and according as it is more or less oxidated, it will be more or less emetic. However, a transparent vitreous oxide of antimony, levigated, and boiled in water with an equal quantity of tartareous acidulum, till the latter be completely saturated, then filtrated and evaporated by a moderate heat, affords, by rest and cooling, crystals of antimoniated tartarite ; the effects of which, as emetics, may be safely depended upon. Decant the liquor, evaporate it, and you obtain by successive evaporation a new quantity of crystals. The mother-water contains sulphur and tartarite of potash, with a certain quantity of antimoniated alkaline sulphure. When the mixture of tartareous acidulum, vitreous oxide of antimony, and water, which were boiled for the preparation of antimoniated tartarite, is filtrated, there remains on the filter a seemingly gelatinous, yellow, or brown matter, of which Rouelle has taken notice. According to M. Proust, this jelly, when distilled, affords a very inflammable pyrophorus.

Macquer has proposed the use of white oxide, precipitated from muriate of antimony by water, instead of the vitreous oxide of antimony. This oxide is a violent emetic ; and Macquer thought it constant in its effects. Bergman has adopted Macquer's opinion ; and in the laboratory of the Academy of Dijon, tartarite of antimony has been since prepared, according to the method of that chemist and M. de Laffone. This preparation has been very successfully employed : the requisite dose is three grains ; and

does not affect the stomach or the intestines too violently.

Tartarite of antimony crystallizes in trihædral pyramids. It is very transparent; it is decomposed, and rendered carbonaceous by fire; in the air, it effloresces, takes a dead white colour, and becomes farinaceous. It dissolves in sixty parts of cold water, and in a much smaller proportion of boiling water; it crystallizes by cooling; alkalis and lime decompose it. Calcareous earth and pure water in a large proportion, are capable of decomposing it; and it should therefore be administered only in distilled water. Alkaline sulphures, and sulphurated hydrogenous gas, produce in its solution a precipitate of a red powder, which is a kind of sulphurated oxide of antimony; and may be employed to ascertain the presence of this salt in any liquor with which it may happen to be mixed. Iron seizes the tartareous acid, and separates the oxide of antimony: stibiated tartar, therefore, should not be prepared in iron vessels. M. Durande, a physician and professor at Dijon, has proposed, that this medicine should be publicly prepared by one uniform process, in the same manner as theriaca. Such a method could not but be very advantageous; the physicians might then all depend on the effects of this medicine. It appears that tartarite of potash which entered into the composition of the tartareous acidulum; and is therefore a sort of triple salt. The tartareous acid may be combined with mercury in two ways. The one, which is mentioned by M. Monnet, consists in dissolving in boiling water six parts of the tartareous acidulum with one part of oxide of mercury, precipi-
tated

tated from the nitric acid by carbonate of potash. This liquor, by filtration and evaporation, afforded him crystals, which were decomposed by pure water. The second method of combining mercury with the tartareous acidulum, is, by pouring a nitric solution of this metal into a solution of tartarite of potash or soda : a precipitate is thus obtained, which consists of mercurial tartarite ; and the nitrite of potash or soda remains dissolved in the liquor.

The tartareous acidulum acts in a sensible manner upon oxide of lead. Rouelle the younger observed, that the tartarite of lead formed in this operation does not remain dissolved in the liquor ; and that the liquor, when evaporated, affords only pure tartarite of potash, which existed, ready formed, in the tartareous acidulum. This is one of the processes which he employed to ascertain the presence of potash in tartar.

Copper and its oxides are easily acted upon by the tartareous acidulum : the result is a beautiful green salt, susceptible of crystallization ; but it has not hitherto been carefully examined.

Iron is one of those metals on which the tartareous acidulum acts with the greatest efficacy. A medicine, called *chalybeated tartar*, is prepared by oiling four ounces of levigated iron filings, with a pound of white tartar, in twelve pounds of water. When the tartar is dissolved, the liquor is filtrated ; it deposits crystals ; and these may be repeatedly obtained by evaporating the mother-water. To prepare *tartarized tincture of Mars* ; make a paste of six ounces of iron filings and of white tartar in powder, and a sufficient quantity of water : let this mixture stand undisturbed.

hours ; next, dilute it in twelve pounds of water, and boil the whole for two hours, adding water to supply the room of that which is evaporated ; decant off the liquor, filtrate it, and concentrate it to the consistency of a syrup, adding an ounce of alcohol. Roulle observed, that the potash exists at liberty in this tincture ; and that, by treating it with acids, neutral salts are obtained ; which demonstrate beyond a doubt the presence of the alkali. There are two other medicines formed by the combination of the tartareous acid with iron ; one of these is *soluble martial tartar*, which is a mixture consisting of a pound of *tartarized tincture of Mars*, with four ounces of tartarite of potash, evaporated to dryness. The other is known by the name of *balls of Mars*. These are prepared by putting one part of filings of steel, with two parts of white tartar in powder, into a glass vessel, with a certain quantity of brandy : when the liquor is evaporated, pulverize the mass, and add more brandy, which evaporate again as before : repeat this process till the mixture become greasy and tenacious ; then make it up into balls.

Crude tartar is of great use in dyeing ; hat-makers likewise make use of it.

The several preparations of the tartareous acidulum, which we have here enumerated, are chiefly employed in medicine. The pure tartareous acidulum is thought to be refreshing and antiseptic ; in doses of half an ounce, or an ounce, it acts as a gentle purge, without exciting nausea. Tartarite, both of potash and soda, is frequently taken in doses of a few drams, to assist the action of other purgative medicines. Tartarite of antimony is one of the most useful and most powerful medicines which chemistry

mistry affords. This salt is emetic, purgative, diuretic, diaphoretic, or discutive, according to the doses, and the circumstances in which it is administered. It often produces even all these effects at once. It may be considered as a powerful alterative, happily qualified to remove obstructions in the viscera, when administered in small and repeated doses. It is given as a vomit in doses of from one to four grains, dissolved in a few glasses of water. A grain of it is sometimes mixed with other medicines to assist their action : lastly, It acts as an alterative when taken, half a grain at a time, diluted in a large proportion of water. M. de Laffone has discovered, that tartarite of antimony is rendered very soluble in water, by mixing with it ammoniacal muriate ; and that there results from this mixture a salt of a nature similar to that of ammoniaco-mercurial muriate. This new triple salt cannot but produce very powerful effects on the animal oeconomy. *Chalybeated tartar*, *soluble martial tartar*, and the *tartarized tincture of Mars*, are employed as tonics and aperitives.

Such are the properties of the native tartareous acidulum, or of the tartareous acid, combined by nature with a certain quantity of potash. It was requisite to examine it with care, as it is so very useful, and so very much employed. But this is not the pure tartareous acid ; and it is of no less importance to know the characteristic properties of that substance. M. Retzius has published, in the Memoirs of Stockholm for the year 1770, a process invented by Scheele for extracting and purifying this acid. Into a solution of two pounds of the tartareous acidulum, in boiling water, put washed chalk, till such time as it cease to produce effervescence, and

and there be no longer any of the acid in a state of liberty : the quantity requisite is somewhat more than a fourth part of the weight of the acidulum ; take out the precipitate of calcareous tartarite which is now formed, place it on a filtre, and wash it with cold water ; there are usually thirty-two or thirty-three ounces of it, on account of its containing water. The liquor decanted from above the precipitate, affords by evaporation a quantity of tartarite of potash, which has not been decomposed, equal nearly to half the acidulum employed. Pour upon the calcareous tartarite, in powder, nine and a half ounces of concentrated sulphuric acid, diluted in five pounds five ounces of water ; leave this mixture to digest for twelve hours, stirring it from time to time. Decant the liquor from above the sulphate of lime ; evaporate it, after ascertaining that it contains no sulphuric acid. In order to that, pour into it a few drops of acetite of lead, or salt of Saturn : if the precipitate thus produced be soluble in vinegar, the lixivium may be inferred to contain no sulphuric acid ; but if the precipitate cannot be dissolved in that fermented acid, the lixivium still contains sulphuric acid, which may be separated by digesting it on a certain quantity of calcareous tartarite. Lime may be used instead of chalk in the process for obtaining the tartareous acid : But as that alkaline earth decomposes the tartarite of potash contained in the tartareous acidulum, the lixivium, when lime is used, contains only alkali instead of tartarite of potash, as in the former process. The use of quicklime in this decomposition affords more of the acid, because lime decomposes twice its weight of tartareous acidulum.

The

The pure tartareous acidulum obtained in a liquid state by either of these processes, must be evaporated to dryness; then dissolved again, and crystallized, either by slow evaporation, according to M. Pæcken; or by cooling the evaporated liquor to the consistency of a clear syrup, according to Bergman. It is obtained in the form of small sharp-pointed needles, or minute prisms; the form of which it is scarce possible to determine. Bergman describes them as divergent leaves; M. Retzius compares them to hairs intertwined together: They are at first very white; those obtained towards the end of the operation are yellow.

The crystallized tartareous acid melts, fumes, becomes black, and even takes fire, when brought into contact with burning bodies. When distilled, it affords, like the tartareous acidulum, only an acid phlegm, a little oil, and a good deal of gaseous carbonic acid, mixed with carbonated hydrogenous gas. The coal which remains contains neither acid nor alkali; which proves, that no alkali is formed in consequence of the decomposition of the tartareous acid by fire: this acid, however pure, is always oily. For this reason, it is called the *tartareous acid*, and its salts *tartarites*.

It is not liable to alteration in the air: It is much more soluble than the tartareous acidulum: Its taste is very pungent: It reddens the tincture of violets, as well as that of turnsol. It dissolves aluminous earth, and forms with it an aluminous tartarite, which takes only a gummy or mucilaginous consistency by evaporation.

In combination with magnesia, the pure tartareous

acid forms a salt; which also, instead of crystallizing, gives a sort of gelatinous matter.

By combination with lime, it affords an almost insoluble salt.

A little potash, poured into this solution, precipitates the tartareous acidulum, or *cream of tartar*, in crystals. This discovery, made by Scheele and Bergman, throws more light than any other facts known on the nature of this vegetable salt. No farther proofs are requisite, as M. de Morveau says, to determine the principles of which the tartareous acidulum consists: we know it to consist of tartarite of potash, with excess of acid; but, what is very singular, this acid, naturally very soluble, suddenly loses that property when about half saturated with potash; which, however, is very soluble by itself. This fine experiment also proves, that the tartareous acid is not in any manner altered by Scheele's process; for with about one fourth or one third of its own weight of potash, it forms an acidulous salt, similar in nature to the acidulum from which it was obtained. With a greater proportion of potash, it forms a neutral salt, completely saturated and soluble, which is tartarite of potash, or *vegetable salt*.

The tartareous acid, with soda, forms a crystallizable neutral salt, or tartarite of soda (*salt of Seignette*), which is very pure. With ammoniac, it affords a crystallizable ammoniacal tartarite. M. Retzcius informs us, that the tartareous acid, when combined with a quantity of ammoniac considerably less than what is required to saturate it, forms a scarce soluble ammoniacal tartareous acidulum, which crystallizes like the
common

common cream of tartar, or tartareous acidulum of potash.

Although the tartarites have not so strong an affinity with the alkalis, as the mineral acids; yet these latter salts, when they decompose tartarite of potash or soda, do not completely separate the base, but disengage the tartareous acid into the state of acidulum, of potash, or of soda. The pure tartareous acid does itself partly decompose sulphate, nitrate, and muriate of potash, and separates so much of the alkali as is requisite to bring it into the state of tartareous acidulum, or acidulated tartarite of potash. It does not produce the same effect on nitrate and muriate of potash.

M. Hermstadt asserts, that the tartareous becomes oxalic acid by means of the nitrous acid. Bergman could not effect this change: but he failed probably on account of employing too little of the nitrous acid. As the nitrous acid gives out nitrous gas, when it accomplishes the transmutation of the tartareous acid, the only difference between the tartareous and oxalic acids would appear to be, that the latter contains a greater quantity of oxigene.

The tartareous acid is incapable of acting on silver, gold, or platina; it dissolves their oxides. Its action on copper, lead, and tin, is imperceptible: it dissolves the oxides of these metals, and destroys the red colour of oxide of lead.

It dissolves iron with a very gentle effervescence.

It produces no alteration on antimony in a metallic state, but acts with sufficient force to dissolve its oxides.

It separates lime from the nitric, the muriatic, the acetous, the formic, and the phosphoric acids.

It precipitates the nitric solution of mercury, the muriatic solution of lead, &c.

Its attractions are represented by Bergman in the following order: lime, barytes, magnesia, potash, soda, ammoniac, aluminous earth; oxide of zinc, iron, manganese, cobalt, nickel, lead, tin, copper, bismuth, antimony, arsenic, silver, mercury, gold, platina, water, and alcohol.

§ II. *Of the Oxalic Acidulum, or Salt of Sorrel, that is sold in commerce, and of the pure Oxalic Acid.*

THE salt of sorrel sold in the shops, or the oxalic acidulum, is extracted in great quantities at Hartz, in Thuringia and Swabia, from the juice of sorrel, called by Linnæus *oxalis acetosella*. An hundred pounds of this plant, cut down in a state of vigorous vegetation, afford, according to M. Savary, fifty pounds of expressed juice; which fifty pounds of juice afford only five ounces of concrete salt, by evaporation and crystallization. The salt of sorrel that comes from Switzerland, is distinguished in commerce as the most beautiful and the whitest; that from Forets in Thuringia is dirty and yellowish.

The juice of sorrel has been long known to afford an acid salt by evaporation. Duclos mentions it in the Memoirs of the Academy for 1668: Juncker likewise speaks of it. Boerhaave, who compares this salt to tartar, has given a very accurate description of the process

process for obtaining it. M. Margraff discovered, that potash entered into the oxalic, as well as into the tartareous acidulum. But the nature of this salt was by no means exactly known, till the experiments of Messrs Savary, Wenzel, Wiegleb, Scheele, and Bergman, were communicated to the world.

The oxalic acidulum exists in small white crystals, opaque, and needled or lamellated. Their form has not been yet fully ascertained; although Capeller and Ledermuller have described them as they appeared through the microscope. M. de Lisle represents them as very oblong parallelopipids. They consist of collections of long thin leaves, joining at one end, but separate at the other. The taste of this salt is sour, poignant, and at the same time bitter. It communicates a deep red colour to tincture of turnsol, and blue paper. Four hundred and eighty grains of this acidulum, distilled in a retort by a fire, the heat of which was properly regulated, afforded M. Wiegleb one hundred and fifty grains of phlegm, strongly acid, without either smell or colour. There remained one hundred and sixty grains of grey salt, from which one hundred and fifty-six grains of vegetable alkali were obtained. About four grains of concrete acid salt were likewise sublimed into the neck of the retort: not a drop of oil passed. In this process of distillation, there were one hundred and sixty-six grains of loss. But as M. Wiegleb does not mention what elastic fluids were disengaged in this analysis, the loss was probably owing to the disengagement of water in vapours, and of carbonic acid gas, mixed with a little hydrogenous gas and carbonaceous matter. By comparing this analysis

with that of the tartareous acid, we perceive the oxalic acidulum to be less oily than the other. The liquid acid, therefore, obtained by this distillation, is pure oxalic acid; whereas the tartareous acidulum, when treated with fire, affords an altered acid, different in nature from the tartareous acid, which we call the *pyro-tartareous acid*. It is because the acid of sorrel contains so little oil, that we call it the *oxalic acidulum and acid*; while to the more oily acid of tartar, the rules of our methodical nomenclature require us to give the name of the *tartareous acid*.

The oxalic acidulum, when pure, suffers no alteration by exposure to air; it is more soluble than the tartareous acidulum. According to M. Weiglib, a drachm of oxalic acidulum from Switzerland requires to dissolve it only six drachms of boiling water; but though other six drachms of cold water be added, it is entirely precipitated by cooling. According to M. Wenzel, it is even much more soluble than M. Weigleb represents it: for he found, by experiment, nine hundred and sixty parts of boiling water to take up six hundred and seventy-five parts of this salt: but its solubility varies, according as it is more or less acid; which again depends on the quality of the plant from which it is extracted.

The oxalic acidulum combines with barytes, magnesia, soda, ammoniac, with which it forms triple salt (or *trifules*). Lime decomposes it, by detaching its acid, both that part which is in a state of liberty, and that which is in combination with the potash. One hundred grains of chalk decompose one hundred and thirty-seven grains of the oxalic acidulum. The pre-

cipitate

precipitate of calcareous oxalate that is deposited, weighs one hundred and seventy-five grains; the supernatant liquor affords, by evaporation, thirty-two grains of carbonate of potash. This process cannot be used in preparing the pure oxalic acid, though the tartareous acid be obtained pure by it: for calcareous oxalate is not decomposable by sulphuric acid, like calcareous tartarite; on the contrary, the oxalic acid has so strong an affinity with lime, that it attracts this earth from all other acids; and one certain test of the purity of the oxalic acidulum, or salt of sorrel, is, to pour a solution of it into water impregnated with calcareous sulphate: when the acidulum has been really extracted from sorrel, it produces in the water a copious precipitate.

The sulphuric acid contributes to the disengagement of the oxalic acid from the acidulum by means of heat, according to M. Weiglib. The nitric acid decomposes the acidulum, and separates the alkali; but it has much more difficulty to accomplish this on the oxalic than on the tartareous acidulum, according to Margraff's experiments.

The oxalic acidulum acts upon iron, zinc, tin, antimony, and lead. It dissolves the oxides of all the other metals, forming with them triple crystallizable salts, which are not deliquescent, and in which the potash always remains in union with the acid: it precipitates the nitric solutions of mercury and silver. M. Bayen, by evaporating the supernatant liquor from above these precipitates, obtained nitrate of potash, and thus established more certainly the existence of alkali in this

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To prepare the oxalic acid by separating the potash of the acidulum, distillation, as we have already seen, may be employed : but this process affords only a small quantity ; and that which Scheele has recommended, being easier performed, and more certain in its results, is therefore preferable. Saturate the oxalic acid with ammoniac ; pour into this triple solution, consisting of oxalic acid, with ammoniac and potash, a quantity of barytic nitrate. A precipitate of barytic oxalate is thus produced, and the nitric acid retains the potash and ammoniac. After washing the barytic oxalate, decompose it with sulphuric acid. The sulphate of barytes, that is now formed, remains insoluble at the bottom of the liquor. Decant off the liquor ; separate the portion of sulphuric acid which may still be contained in it, by barytic oxalate dissolved in boiling water ; and when it ceases to afford a precipitate, the liquid may be considered as containing pure oxalic acid, and decanted off from above the precipitate. It is next to be evaporated with proper care ; and it now affords salt, by cooling, in quadrilateral prisms, with their sides alternately broad and narrow, and terminating in dihedralsummits. These crystals are often in the form of square or rhomboidal plates.

This concrete acid has a very strong sour taste ; seven grains communicate a sensible acidity to two pounds of water. It reddens all blue vegetable colours. A grain of this salt communicates to 3600 grains of water the property of reddening paper tinged with turnsol.

The concrete oxalic acid, when exposed to a moderate fire, becomes dry, and is covered over with a thick crust; it is in a short time reduced to powder, and loses three tenths of its weight. When distilled in a retort, by a stronger fire, which must not, however, be violent, it liquifies, becomes brown with ebullition, affords an acidulated phlegm, and is partly sublimated without alteration. There is at the same time disengaged from it a gas, mixed with carbonic acid, and hydrogenous gas. When exposed to a violent heat, it affords more gas, less sublimated concrete acid, and more acidulated phlegm, that is not liable to crystallization; at the bottom of the retort, there remains only a grey or brown mass, amounting to one fiftieth part of the acid employed. When put upon a coal burning in the air, it emits a very acrid white smoke, which irritates the lungs in a very lively manner: the residue which it leaves is white, without any mixture of carbonaceous matter. Such is the result of the decomposition of the oxalic acid by fire that was observed by Bergman. The Abbé Fontana has obtained near double the quantity of gas; but that, as we have already shown, depends on his having applied a stronger heat, with a view to effect a thorough decomposition of the acid.

When exposed to moist air, the concrete oxalic acid remains deliquescent; but in dry air it rather becomes dry. Cold water dissolves a quantity of it equal to one half of its own weight. When crystals of this acid are cast into cold water, a faint noise is heard, which must be produced by a sudden breaking of their particles. The specific gravity of this cold solution is 1.0593, ac-

cording to M. de Morveau. No acid vapour rises with the water of the solution when evaporated, not even by ebullition. Boiling water dissolves a quantity of this concrete acid salt equal to itself in weight : One half is precipitated in crystals by cooling.

The oxalic acid dissolves aluminous earth. This solution affords, by evaporation, a yellowish mass, transparent, soft, and astringent ; which attracts moisture from the atmosphere, and reddens turnsol. This salt swells in the fire ; it then loses its acid, and the aluminous earth remains a little coloured ; It is decomposable by mineral acids.

In combination with barytes, it forms a scarce soluble salt ; which, with an excess of the acid, affords angular crystals. Hot water, by depriving them of that excess, renders them opaque, pulverulent, and insoluble.

With magnesia, it affords a white salt in powder, which is decomposable by the fluoric acid and barytes.

The oxalic acid, saturated with lime, forms a salt insoluble in water, pulverulent, and not decomposable by fire ; for so strong is the affinity between this acid and lime, that it detaches this base from every other acid. On account of this property, Bergman has proposed the use of the oxalic acid for ascertaining the presence and the proportion of lime in mineral waters, or in any combination with other acids. Calcareous oxalate gives a green tinge to syrup of violets.

The oxalic acid combines with potash ; and the neutral salt, with an excess of either of the two principles, is susceptible of crystallization. Oxalate of potash is

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very soluble in water, and decomposable by the action of fire and of mineral acids. Pure oxalic acid, added in drops to a solution of this salt, soon produces a precipitate, which appears to be oxalic acidulum, the same as the common *salt of sorrel*.

With two thirds of soda, the oxalic acid forms a salt which is scarce soluble, but dissolves best in hot water, and turns syrup of violets green. An excess of the acid forms acidulous oxalate of soda, which is scarce soluble.

With ammoniac, the oxalic acid affords ammoniacal oxalate, which crystallizes, by slow evaporation, into quadrilateral prisms. By fire, this salt is decomposed; and then it yields ammoniacal carbonate, formed by the destruction of the oxalic acid. An excess of the acid poured into a solution of this salt, precipitates from it an ammoniacal oxalic acidulum, in crystals much less soluble in water than the pure neutral salt.

The oxalic acid is soluble in mineral acids. It imbrowns the concentrated sulphuric acid; it is decomposed by the nitrous acid, and reduced into carbonic acid in consequence of the decomposition. This acid generally combines much easier with metallic oxides than with the metals themselves.

1. With oxide of arsenic, it forms prismatic crystals, very fusible, very volatile, and decomposable by heat.

2. With oxide of cobalt, a pulverised salt, of a bright rose-colour, and scarce soluble.

3. With oxide of bismuth, a white salt in powder, very little soluble in water.

4. With oxide of antimony, a salt in crystalline grains.

5. With oxide of nickel, a salt, of a white or greenish yellow colour, and scarce soluble.

6. With oxide of manganese, a salt in a white powder, which becomes black in the fire.

7. With zinc, the solution of which is attended with effervescence, a pulverulent white salt.

8. It dissolves oxide of mercury, and reduces it to a white powder, which is rendered black by the contact of light. This acid decomposes mercurial sulphate and mercurial nitrate.

9. Tin, by its action, is first rendered black, and afterwards covered with a white powder. The salt which it forms with this metal is of an harsh taste. It crystallizes into prisms, by evaporation judiciously conducted; when evaporated by an intense heat, it leaves a transparent mass, resembling horn.

10. It tarnishes lead, but dissolves its oxide better. The saturated liquor deposits small crystals, which may also be obtained by pouring oxalic acid into a solution of nitrate or muriate of lead, or into acetite of the same metal.

11. It acts on iron-filings; and as there is water decomposed in this solution, there is of consequence hydrogenous gas disengaged. Oxalate of iron is stiptic: it affords greenish yellow prismatic crystals, decomposable by heat.

Yellowish oxide of iron, in combination with this acid, affords a yellow salt, similar to that which is obtained
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By pouring liquid oxalic acid into a solution of sulphate of iron.

12. It acts on copper, and entirely dissolves the oxides of this metal. The salt thus formed is of a clear blue colour, and scarce soluble. This salt may be likewise obtained by precipitating sulphuric, nitric, muriatic, and acetous solutions of copper, with oxalic acid.

13. Oxide of silver, precipitated by potash, dissolves in a small proportion in this acid. The best way of obtaining this salt is by precipitating the nitric solution of silver with oxalic acid: a white sediment is produced, scarce soluble in water, and liable to become brown by the contact of light.

14. This acid scarce acts on oxide of gold.

15. Lastly, it dissolves the precipitate of platina produced with soda. This solution is somewhat yellow, and affords crystals of the same colour.

Such are the phenomena of the combinations of the oxalic acid, as described by Bergman.

That celebrated chemist accomplished all these combinations with artificial oxalic acid, prepared from sugar and nitric acid. Sugar, as well as all mucilages, extracts, sweet oils, and farina, affords, when treated with nitrous acid, an acid perfectly the same with pure oxalic acid, as has been ascertained by Scheele. All these matters, and even a great many animal substances, as has been discovered by M. Berthollet, contain therefore the radical principle of the oxalic acid, wanting nothing but oxygen to complete the acid.

Bergman

Bergman was the first who discovered that sugar, treated with nitrous acid, formed a peculiar acid : he gave it the name of the *acid of sugar*, or *saccharine acid* ; which it retained for several years, till Scheele showed it to be precisely of the same nature with the oxalic acid, extracted from *salt of sorrel* by the process above described. He showed the identity of these acids, by forming the scarce soluble oxalic acidulum, or *salt of sorrel*, from a combination of a small quantity of soda, with the saccharine acid. Here, then, is a vegetable acid, which exists in an acid state in but few vegetable matters, but of which the base is exceedingly copious in those matters, and appears to pass unaltered into animal bodies. In the following chapters, we shall see that this acid is probably, like all other vegetable acids, a compound of hydrogen, carbon, and oxygen ; and that the only difference between it and the other vegetable acids is in the proportions of their principles.

The base or radical principle of the oxalic acid appears to exist in greater plenty in insipid matters than in sugar ; though it was once believed, that saccharine bodies afforded most of it. From sugar, Bergman obtained only a third part of its weight of oxalic acid : and from wool, M. Berthollet has obtained a quantity equal to more than half the weight of the wool.

The pure oxalic acid is used no where but in the laboratory ; the chief use to which it is there applied, is to ascertain the presence of lime. The oxalic acidu-
lum,

lum, or salt of sorrel, is used to efface stains of ink from white stuffs, wood, ivory, &c. on account of its having so strong an affinity with iron; but the pure oxalic acid being more soluble, might be more advantageously used for such purposes.

CHAP.

C H A P. VII.

Of Vegetable Acids, formed by the Action of Fire, and by the Nitric Acid.

IT has been long known to chemists, that many vegetable matters afford, by distillation, phlegms, or acid liquors: these saline substances, altered by fire, were, however, but little attended to. Since such a number of acids have been discovered, really distinct from one another, either in their intimate nature, or in the proportion of their principles, many of these salts have been found to possess peculiar and distinctive properties. It has been also ascertained, that some acids act, like heat, on vegetable matters, and that the nitric acid, in particular, converts most of them into acid. These new, or newly modified salts, need to be carefully examined, in order that we may acquire a knowledge of their nature. We cannot avoid remarking, in the first place, that there must be a general analogy of nature, or formation, among vegetable acids, produced by the action of heat: On account of that analogy, we give them
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the generic name of empyreumatic salts; and apply to each of them, as a specific distinction, the syllable *pyro*, joined to a term indicating the origin of the salt; thus we say, the *pyro-tartareous*, the *pyro-mucous*, and the *pyro-ligneous* acids.

§ I. Of the *Pyro-Tartareous Acid*.

IT has been already mentioned, that, by the distillation of the tartareous acidulum, an acid phlegm is obtained, which is not the pure tartareous acid, but that acid altered in a particular manner. The hydrogenous gas, and the carbonic acid gas, that are at the same time disengaged, shew plainly that such an alteration must take place; for these can only be produced in consequence of the decomposition of the acid of tartar. As this alteration is owing to the action of heat, and as an oil, mixed with the distilled acid, is at the same time volatilized, which modifies its colour, we have therefore called that acid the *pyro-tartareous*, and its saline combinations *pyro-tartarites*, according to the laws of our nomenclature.

The first chemists who made experiments on this matter, with any degree of accuracy, ascertained, that, by distilling about a quarter of a pound of tartar, there might be obtained an acid phlegm of a very pungent smell, or *pyro-tartareous acid*. The academicians of Dijon represent the secondary rectification or distillation of this acid, which has been recommended by so many authors, as attended with one very great difficulty:—

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adopt to moderate the fire, and give room to the vapours, they always found the liquid to rise so quickly as to burst the vessels containing it, into pieces. This phenomenon they attribute to the action of gas produced by the decomposition of the acid, and compressed by the oil; which pressure it at length overcomes, as it is more dilated. Besides, the rectification is not very necessary, as the acid separated from the oil by the still-pipe is so pure as to exhibit all its distinctive characteristics.

The pyro-tartareous acid has an empyreumatic taste and smell. It does not redden syrup of violets, but it produces that effect on turnsol and blue paper: It disengages the carbonic acid from its bases with a lively effervescence. With the earths and alkalis, it forms salts very different from those which the tartareous acid forms with the same bases. These saline compounds have not yet been examined; only we know the pyro-tartarites of potash and soda, to be soluble in cold water, and crystallizable: the acid decomposes nitrate of silver, producing from it a grey precipitate; it by degrees renders nitrate of mercury turbid; it does not decompose calcareous muriate; and the sulphuric acid decomposes its neutral salts by distillation.

Chemists, before hydrogen, carbonaceous matter, and oxygen, were understood to be the sole and genuine component principles of all vegetable acids, constituting different acids only by being united in different proportions, had adopted opinions very remote from the truth, concerning the nature of this acid, obtained by distillation from tartar. Venel asserted it to be acid of
nitre.

nitre. M. Monnet concluded, from a more accurate investigation of its nature, that it was muriatic acid disguised by oil and mucilage. But although Scheele found tartar to contain a little muriatic acid, yet the cubic form of the neutral salt, produced by the union of the pyro-tartareous acid with soda, and the precipitation of nitrate of mercury by this acid, the two facts on which M. Monnet establishes the identity of the pyro-tartareous with the muriatic acid, are not sufficient evidence to induce modern chemists to assent to the conclusion deduced from them. Besides, the chemists of Dijon have repeated the same experiments without obtaining the same results; nor have Messrs Berthollet, Spielman, and Gorvinus, been more successful. On the contrary, it is highly probable, that the principles of the pyro-tartareous acid are the same with those of the acid of tartar itself; and that the two acids differ only in the proportion of their principles: the smell and taste of this empyreumatic acid, its not being susceptible of crystallization, and all its other properties, and still more the disengagement of oil and carbonic gas from the tartareous acidulum, when the pyro-tartareous acid is formed,—concur to prove the truth of what is here asserted.

The character of this empyreumatic acid has not yet been sufficiently investigated, to enable us to determine the order of its chemical affinities with earthy, alkaline, and metallic bases.

§ II. *Of the Pyro-Mucous Acid.*

THE acid which we denominate pyro-mucous, is that obtained from insipid, saccharine, gummy, farinaceous, &c. mucilages, which was at first denominated by M. de Morveau the syrupous acid. Chemists have long known that sugar affords, by distillation, a pretty strong acid phlegm. Neuman, Cartheuser, Geoffroy, and Bucquet, have made particular mention of that acid, but without having examined its properties. M. Schrickel has examined its nature with more minute attention than any other chemist.

By distilling 16 ounces of sugar, M. Schrickel obtained 6 drachms of phlegm, which passed into the receiver in the form of white vapour, and was condensed into unctuous striæ, of a pungent smell, like that of horseradish, or bitter almonds, roasted; of an acid, acrid, and bitter taste, and of a red yellow colour. He rectified this acid upon clay; it then passed clear, with a less pungent smell, and a sour taste. This acid, when thus purified, did not crystallize; but when exposed to cold, the aqueous part froze, and that part which still remained liquid, became much more concentrated.

M. de Morveau observed, when preparing the pyromucous acid by the distillation of sugar, that the bottom of the retort was corroded during the operation. He does not attribute this to the acid, as it exhibits no such property when rectified, or when left long in the glass; but rather to the action and adhesion of the carbure of iron, which exists in the coal that remains after the decomposition of the sugar, and had been violently heated. This acid, therefore, cannot be concentrated

by volatilizing the water that is united with it, as the salt is no less volatile than the fluid. This acid, according to M. de Morveau, exists in molasses, and renders them deliquescent, and not susceptible of crystallization.

The pyro-mucous acid, when concentrated by freezing, is very pungent, and communicates a deep red to blue vegetable colours. It produces red spots on the skin, as was long ago observed by Cartheuser; and the spots thus produced destroy the epidermis before they disappear. When exposed to fire, it is totally volatilized, leaving no residue but a brown mark on the place where it lay. Most of it may be converted into carbonic acid gas, and hydrogenous gas, by distilling it, with proper precautions, in close vessels: it now affords a more copious carbonaceous residue than when heated in open vessels. A part is volatilized without alteration.

When combined with barytes, magnesia, lime, potash, soda, and ammoniac, it forms neutral salts, which we call *pyro-mucites*, the properties of which have not yet been examined with sufficient care, but which differ from all other known neutral salts. It disengages the carbonic acid from all of these alkaline bases with a lively effervescence.

The property of dissolving gold was formerly ascribed to the spirit of honey; but it appears for certain, that the pyro-mucous acid does not affect either that metal, or platina, or silver, or even mercury; but it might possibly dissolve the oxides of these metals. This acid corrodes lead, becoming opaque itself on the occasion; which alteration it owes to the oxide of lead which it

forms. Pyro-mucite of lead is in oblong crystals. It acts upon copper, and becomes green by the re-action of that metal ; it dissolves tin ; it acts upon iron, and combines with that metal to form crystals.

Its chemical affinities have been determined by M. de Morveau in the following order ; Potash, soda, barytes, lime, magnesia, ammoniac, aluminous earth, metallic oxides, water, alcohol.

This empyreumatic acid has not as yet been applied to any purpose. Spirit of honey, of manna, &c. were formerly made use of in pharmacy ; but the use of them has been long given up.

§ III. *Of the Pyro-ligneous Acid.*

WOOD, especially beech, birch, and box trees, afford, by distillation, a brown acid liquor, of a pretty strong, peculiar smell, which reddens blue vegetable colours, and effervesces with alkaline carbonates. Boerhaave was acquainted with the product of box, juniper, oak, and *Guayac* : but the chemists who have repeated Boerhaave's process, have not examined the nature and peculiar properties of this acid. M. Goettling, in the year 1779, first published, in Crell's Journal, a Memoir on the acid of wood, and more especially on its union with alcohol. That chemist distilled the bark of birch in an iron retort : he obtained a brown, oily, acid product, which he left to settle for three months ; at the end of that time, he observed drops of oil swimming on its surface, which having separated by filtration, he poured into the filtrated liquor a solution of potash. A
lively

lively effervescence took place; the liquor assumed a blood-red colour, and afforded, after being saturated with alkali, and evaporated, a black salt, which was melted in an iron pan, and purified by a second solution, and a second evaporation.

The pyro-ligneous acid may be also rectified by distillation, according to M. Goettling. The pyro-lignite of potash, formed of this rectified acid, becomes very hot when brought into contact with the sulphuric acid, and affords pyro-ligneous acid in a state of considerable purity. That chemist, to whom we are indebted for these facts, observes, that the pyro-ligneous acid, when separated by the sulphuric acid, has no longer any empyreumatic odour, but a smell of garlic.

The chemists of Dijon extracted this acid from beech, by distillation, and afterwards rectified the liquid product: 55 ounces of this wood, well dried, and in shavings, afforded 17 ounces of rectified acid, of an amber-colour, not mixed with oil, and of which the gravity was to that of distilled water, in the proportion of 49 to 48: 23 $\frac{1}{2}$ ounces of lime-water were required to saturate an ounce of this acid. When exposed to a gentle heat, it ascends in vapour. A strong heat decomposes this, as well as all other vegetable acids. It cannot be obtained in a concrete form.

It combines with earthy and alkaline bases, and forms with them peculiar salts, which we call pyro-lignites of aluminés, barytes, magnesia, lime, potash, soda, and ammoniac. These salts have not yet been examined with sufficient care to enable us to give here a particular account of them. M. Eloy Bourcier de Clervaux has communicated, in the Lectures of Ché-

mistry of Dijon, some experiments very suitable to determine the elective attractions of the pyro-ligneous acid. Calcareous and barytic earths adhere to it with greater obstinacy than the alkalis; lime has a stronger affinity with it than barytes; and magnesia a stronger than ammoniac; and even these affinities may serve to distinguish it from most other vegetable acids. It acts also upon many of the metals, and dissolves most of their oxides.

All kinds of wood, it appears, would afford the same acid by distillation; for box, birch, and beech, agree in affording one acid. But much inquiry, and many experiments, are necessary, before we can be fully acquainted with the characteristic properties of this acid.

§ IV. *Of Vegetable Acids, formed by the Nitric Acid.*

BERGMAN has proved, that the nitric acid converts sugar into an acid, which, being at first thought peculiar and different from all others, was therefore called the saccharine acid. Scheele has shown this salt to be precisely the same with that which is in part neutralized by potash, in salt of sorrel: this very salt is therefore in every respect the same with the oxalic acid. Several modern chemists, and especially M. Berthollet, have proved, that almost all animal and vegetable matters afford this acid, when treated with the acid of nitre. It is therefore certain, that the base or radical principle of the oxalic acid exists in a great many bodies, and, in general, in all bodies which have been formed by vegetation, or the functions of animal life. The nitric acid acts in an equal and uniform manner on all such substances;

stances ; it always gives up to them either more or less of its oxigene, and passes into the state of nitrous acid, nitrous gas, or even azotic gas, according as it is deprived of a greater or a less proportion of its oxigene. As the base, or radical principle of the oxalic acid, is more or less copious in the various organic matters in which it is found ; these matters afford more or less of this acid, when treated with nitric acid. At the same time, when the acid of nitre is decomposed by organic substances, together with nitrous or azotic gas, there is also disengaged a certain quantity of carbonic acid gas, which proves the organic matter to have lost a part of its carbonaceous substance, and at the same time shews the oxalic acid, thus produced, to contain less of that principle than the substance from which it is obtained. Since a number of vegetable acids, particularly the tartareous acid, &c. pass into the state of oxalic acid, in consequence of being exposed to the action of nitrous acid ; and since carbonic acid is disengaged while this change takes place ; it follows plainly, therefore, that all the vegetable acids have the same radical principle, and differ only in their proportions of oxigene.

In the *Nouvelles de la Republique de Lettres* for the year 1785, No. 42. and 44. it was related, that M. Kosegarten, by distilling nitric acid on camphor, eight times successively, had obtained from that matter a concrete acid, in parallelipiped crystals, of bitter taste, and capable of reddening the tincture of violets and turnsol. That salt, according to this chemist, differs from oxalic acid, as being incapable of separating lime from the muriatic acid. With potash, it forms a salt in regular hexagons ; with soda, a salt in irregular crystals ; with ammoniac,

ammoniac, prismatic, or needled crystals; with magnesia, a soluble, pulverulent salt. It dissolves copper, iron, bismuth, zinc, arsenic, and cobalt. But these facts, which have not yet received confirmation, are not sufficient to enable us to enter into a minute account of the properties of this acid, which is, perhaps, nothing but a particular modification of some one of those of which we have already spoken. And if farther experiments on this acid shall discover it to possess peculiar properties, different from those of the other acids, its nature and characteristic properties must then be examined under the name of the camphoric acid, and its neutral salts will be called *camphorates*.

M. Brugnatelli discovered, in the year 1787, that cork, on which he distilled four times its own weight of nitrous acid, left a yellowish mass, thick, acid, soluble in water, and of a sour, or rather a bitter taste. This acid is not susceptible of crystallization; when evaporated by a strong heat, it takes the form of a viscous mass, like wax, which is so soft that it may be moulded with the fingers. It is soluble in alcohol; on burning coals, it is reduced to a coal without inflammation; with earths and alkalis, it forms deliquescent salts, many of which crystallize: lastly, it has as strong an affinity with lime as the oxalic acid, and forms with that earth a salt that is not soluble in water, but may be dissolved in muriatic acid. Without presuming to speak decisively of the peculiar nature of this acid, M. Brugnatelli appears, however, to think it different from the oxalic acid. Future experiments must determine whether this be really a peculiar acid meriting a separate examination; and we must, in the same manner, leave the particular nature
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of that which has been discovered by Messrs Proust and Angulo, in the neighbourhood of Madrid, on the surfaces of grey pease, in vesiculæ at the extremity of the hairs of that leguminous plant, equally undetermined.

Thus we have given an account of all known vegetable acids. We have still, however, to treat of those which are formed by fermentation. But as the chief, nay, the only one of these acids that is known, is produced in consequence of an alteration taking place on liquors that are already fermented, we will give its history immediately after that of spirituous fermentation, and its product.

C H A P.

C H A P. VIII.

Of Saccharine Matter, Gums, and Mucilages.



THE saccharine matter, which many chemists think to be a sort of essential salt, is found in a great many vegetables, and is to be considered as one of their immediate principles.—The maple, the birch, the red beet, the parsnip, the grape, wheat, &c. are found to contain it. Margraff extracted it from most of these vegetables. The petals of many flowers, and the nectaria placed in those organs, prepare a principle of this kind.

The sugar-cane, *arundo saccharifera*, is the plant which contains the most of it, and from which it is extracted with the greatest advantage. The sugar-canes are crushed to pieces between two iron cylinders, in a perpendicular position. The expressed juice falls upon a plain surface underneath; and is called *melasses*. It runs off this surface into a boiler with ashes and lime, where it is boiled and skimmed; and, in the same manner, it is successively boiled and skimmed in three other boilers; and, after undergoing these boilings, it receives the
name

name of syrup. It is after this boiled anew, by a strong heat, and for a considerable time, with lime and alum. After being sufficiently boiled and concentrated, it is poured into a vessel called *the cooler*. When it is so cool that the finger may be dipped in it without injury, it is poured into large barrels standing over cisterns, and the bottoms of which are perforated with holes stopped with canes. In the barrels, the syrup takes the form of a solid mass, part of it running off into the cisterns. The sugar, when thus rendered concrete, is yellow and unctuous; it is now called *muscovado*. In the sugar-islands, it is refined by boiling it, and then pouring it fluid into inverted cones of earthen ware, called pans. That part which cannot be rendered concrete runs through a hole in each of the pans, into a pot placed below; it is called *coarse syrup*. The base of the sugar-loaf is taken away, and white sugar in powder put into its place, and pressed well down: The whole is then covered with pure moist clay. The water of the clay filtrates through the sugar, carrying off with it a portion of the mother-water of the sugar, which runs out by the holes in the pans, and is received into new pots. This is called *fine syrup*, as being purer than the former. A second layer of clay is laid on when the first becomes dry, and the water filtrates through, a second time: When the water contained in the second layer of clay is drained off, the loaves are removed into a stove to dry. At the end of eight or ten days these loaves are broken, and sent into Europe in the form of brown sugar, which is here refined into sugar of different qualities.

The refining of sugar is accomplished by b it in
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lime-water, and with bullock's blood, skimming it two or three times, filtrating the liquor, and running it in pans, to give it the shape of loaves. These loaves are then coated over with wet clay, the water of which is suffered to filtrate through them. The filtration is repeated with fresh clay, till the sugar become sufficiently white. The loaves are then removed into a stove, and at the end of eight days are wrapped up in a paper for sale. The *syrup* which cannot be crystallized is called *molasses*.

Chemists have universally been of opinion, that these different operations separated from sugar a fat matter, and thereby rendered it susceptible of crystallization. Bergman thinks, that the use which the lime serves is, to carry off the excess of acid, which hinders it from taking a solid form. The acid can be no other than the pyro-mucous acid which is formed by heat, as we have related in the foregoing chapter. As the liquor is exposed, during the operation, to a violent evaporation, it becomes a granulated, irregular mass, agreeably to what has been already observed of sulphate of zinc.

Sugar is a substance in some measure of an intermediate nature between essential salts and mucilages. It crystallizes in truncated hexahædral prisms. In this state it is called *sugar-candy*. It affords, by distillation, water, pyro-mucous acid, and a few drops of empyreumatic oil. There is at the same time disengaged from it a considerable quantity of carbonic acid gas, and of hydrogenous gas, with coal dissolved in it. The residue is a spongy light coal, containing a little carbonate of potash.

Sugar is inflammable: When laid on burning coals, it melts and swells; it exhales a very pungent acid vapour;

our ; it takes a brown-yellow colour, in consequence of which it receives the name of *caramel*. It dissolves very readily in water. It communicates to it a considerable consistency, forming with it a sort of saccharine mucilage, which has received the name of *syrup*. This syrup, when diluted in water, is susceptible of fermentation ; it may even be converted into a vinous liquor, and alcohol distilled from it.

Bergman prepared from all the different saccharine matters, especially from sugar,—oxalic acid, by means of the nitric acid. To obtain that acid from these matters, put into a retort one part of sugar in powder, with six of nitric acid : Expose the mixture to a moderate heat ; continue the evaporation for some time after red vapours cease to pass ; leave the solution to cool ; and it then precipitates white needled or prismatic crystals, which are concrete oxalic acid.

Sugar is very much used.—It is an article of food ; which, when taken in too large a quantity, heats the animal system. It is much used in pharmacy, being the basis of syrups, lozenges, and some other preparations. It contributes to dissolve and suspend in water, resins, oils, &c. It serves to preserve fruits reduced to jelly. It may be even considered as a medicine ; for it is incisive, aperitive, and, in a slight degree, tonic and stimulant : And accordingly there are some instances related, in which disorders arising from obstructions have been cured by the continued use of sugar.

There are some juices of plants which have a taste of sugar. Manna and nectar are of this kind. Manna is obtained from the leaves of fir, oak, juniper, &c. and maple-trees, &c. The ash, which is very, plentiful in Calabria

Calabria and Sicily, affords that which is commonly fold. It runs naturally from those trees, but is obtained in still greater abundance by making notches in the bark of the tree.—That which is received on chips of wood, or small sticks introduced into artificial apertures in the trees, takes the form of hollow stalactites, and is called *manna in tears*. *Manna in flakes* runs down the bark, and contains some impurities. The inferior unctuous sort contains many extraneous matters, and is formed from the refuse pieces of the two former. It is always humid, and frequently altered. The taste of manna is mild and inlipid : That which the larch-tree that abounds in Dauphiny affords, and that of the alhagi, which grows in Persia, around Mount Tauris, are not in use ; the latter bears the name of *tereniabin*.—Manna is soluble in water ; it affords, by distillation, the same products as sugar. There is extracted from it, by means of lime and white of eggs, a matter resembling sugar, which, when treated with the nitric acid, affords concrete oxalic acid.

It is given as a purgative, in dozes of from one to two or three ounces ; or, when it is given as a discussive, a few drachms of it are diluted in a large proportion of water.

Another sort of proper juice is that called *gum* or *mucilage*. This substance is very plenteous in the vegetable kingdom. It is found in a great many roots : Young stems and leaves, immediately after their appearance, contain a good deal of it. This principle may be known by its viscous adhesive property. In the season when the juice is most copious, it runs naturally down the bark of trees, and thickens into gum on the surface.

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The gum is soluble in water, to which it communicates a thick viscid consistency. This solution, known by the name of *mucilage*, becomes, when evaporated, dry, transparent, and friable.

Gum burns without emitting any perceptible flame. It melts and swells upon coals. It affords, by distillation, a good deal of water and pyro-mucous acid, a little thick brown oil, and carbonic acid gas, mixed with hydrogenous gas: The residual coal is very bulky, and contains a little carbonate of potash.

We know of three sorts of gum that are used in medicine, and in the arts.

1. The gum of the apricot, the pear, and the plum tree, &c. It is either white, yellow, or reddish; the best of this sort of gum may be applied to the same purposes as the other gums. A kind of gummy juice, of a beautiful orange-colour, flows from the elm; considerable quantities of it are sometimes found on the bark of the tree. I have found this gum to possess the properties of insipidity, insolubility, viscosity, with the other characteristics belonging to such juices.

2. Gum Arabic, which runs from the acacia in Egypt and Arabia. Gum Senegal is of the same kind; it is used in medicine as a mitigating and relaxing remedy. Crayons, and some other such compositions, are indebted to it for their consistency. It is used in various arts.

3. Gum Adraganth, which flows from the adraganth of Crete; *Astragalus Tragacantha*. It is administered in the same cases as Gum Arabic; the solution of it is somewhat thicker than the solution of Gum Arabic; it soon

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deposits viscid flakes, and requires more water to dissolve it.

Mucilages, of the same nature with gums, are obtained from various plants. The roots of mallows, marshmallows, the greater comfrey, the bark of elm, lintseed, the seeds of quinces, &c. afford, by maceration in water, viscous fluids; which, when evaporated to dryness, afford real gums. In medicine, decoctions of these plants are used instead of solutions of gums.

All of these matters, chemically considered, appear at first view to be nearly simple bodies; for chemical operations often offer to our observation substances of a gelatinous form, much like that of gums and mucilages; yet, from these products of vegetation, which appear to form a sort of excrementitious humour, are extracted water, liquid pyro-mucous acid, carbonic acid, an oily principle, and fixed alkali united to a coaly residue. This residue likewise contains a fixed earth, the nature of which is still unknown.

When mucilages and gums are treated with nitric acid, and its action assisted by heat, they afford oxalic acid in crystals. They contain therefore the oily or radical principle, which, in combination with oxygen, constitutes this acid.

This analogy between mucilage and saccharine matter is farther observable in that the smell of burnt gum is much the same with that of caramel—that the products which both afford by distillation are of a similar nature—and that the bulk and levity of the residual coal are the same in both. Some of those fruits which become saccharine, such as apricots, pears, &c. exude, before they become ripe, a real gum. That sort of dry mucilage which

we are hereafter to examine under the name of *amylaceous secula*, seems to be converted into saccharine matter by germination. These facts, and many others which might be joined with these, shew that there is a near relation between sugar and gum. Perhaps the insipid or gummy mucilage passes by a sort of fermentation into the state of a saccharine body. Were this an ascertained fact, this fermentation would come in order before that which Boerhaave has called *spirituous fermentation*; and must constantly precede it, both in the natural process of vegetation, and in the operations which art employs to produce the saccharine taste in barley, &c.

C H A P. IX.

Of Oils of a fixed Nature, that are extracted by Expression.

OILS are proper juices, of a fat, unctuous nature, either fluid or solid, not soluble in water, liable to burn with flame, volatile in various degrees : They are contained in the proper vessels, or in particular vesiculæ. These bodies are found existing in two states in vegetables : They are either combined with other principles, as in extracts, mucilage, &c. or they are free, and not united with any other principle. These latter oily juices are those of which we are here to speak.

Chemists have supposed the existence of a simple oily principle, as well as of a primitive salt. This oily principle, combined with different substances, and modified by those combinations, constituted, according to them, the various sorts of oils that were obtained by analysing vegetables. The characters which they ascribed to that simple primitive oil, were, great fluidity, an high degree of volatility, privation of colour and smell :—It burns

with flame and smoke:—It did not combine with water:—It was thought to consist of water and an acid combined with an earth and *phlogiston*. It is certain that oils, when decomposed, always afford a small quantity of acid, and a good deal of hydrogenous gas: earth constitutes but a very small part of them, for they leave but very little fixed carbonaceous residue. This notion of the oily principle deserves to be viewed only in the light of an hypothesis.

Oils are never formed by any but organic beings; and such bodies in the mineral kingdom as are of an oily nature, always owe their origin to the action of vegetable or animal life. It is even highly probable, that vegetables are the only bodies in which oils are formed; and that they pass without alteration from vegetable into animal bodies.

The oily juices of vegetables are distinguished into fixed oils and volatile oils.

Fixed oils, called also *fat oils*, *sweet oils*, *oils by expression*, are very unctuous: they have generally a mild and insipid taste, and no smell; the heat requisite to volatilize them is above that of boiling water; and they never take fire till they are brought to that degree of heat which is requisite to volatilize them.—It is for this purpose the wick used in burning fixed oil in lamps is employed; it heats the oil to volatilization.

Most fixed oils are fluid, and require no considerable degree of cold to render them solid: Others, again, lose their fluidity by the slightest cold; and, lastly, there are others always solid: These last are called, but very improperly, *vegetable butters*.

Fixed oils never flow from the surfaces of vegetables; They are contained in the kernels, the pippins, and emulsive seeds. They are extracted by bruising the little cells in which they are contained; that is, by pounding and squeezing.

Fixed oils, when exposed to the air, are altered, and become rancid; their acid is liberated; they lose the properties which they possessed, and acquire others, in consequence of which they are nearly assimilated to volatile oils. Water and alcohol carry off the acid, and thus destroy their rank taste, but never restore them to their primary state. M. Berthollet has discovered, that fat oils, when exposed to air, by being thinly spread over the surface of water, become thick, and assume pretty much the same appearance with wax. It is at present known as an undeniable fact, that this thickening of oils is owing to their absorbing oxigene from the atmosphere; for all substances that contain this principle, and resign it to fixed oils,—as for instance, many of the acids, especially the oxygenated muriatic acid, and metallic oxides,—thicken fixed oils, and reduce them to a state in which they resemble wax.

Fixed oils afford by distillation a little water, containing a very acrid pungent acid, some light oil, a thick oil, and a large quantity of hydrogenous gas, mixed with carbonic acid: They leave but very little residual coal. By distilling these products a second time, pure sebacic acid is obtained, of which we will have occasion to speak in the animal kingdom, and some oil, still lighter than what was before obtained.—This oil is improperly called *philosophers oil*. The alchemists prepared it by distilling several times successively, a brick impregnated with fixed
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oil. It is not perfectly known how far this decomposition may be carried : formerly, indeed, it was said that a fixed oil might be reduced to a free inflammable principle ; into water, acid, air, and earth.

Cold water effects no alteration on fat oils ; it purifies them by carrying off a part of their mucilage, which is likewise precipitated when they are submitted to combustion, and is the principle that renders them susceptible of fermentation, and liable to become rancid.—It is well known, that water cast upon these oils, when burning, instead of quenching, causes them to burn with new violence : the reason of which is, that the water, being decomposed, supplies oxigene to the oil, and at the same time gives out a good deal of hydrogenous gas. When the vapour which proceeds from fixed oil in combustion, is collected into a chimney terminating in a worm-pipe, a considerable quantity of water is obtained ; which proves this immediate principle of vegetables to contain hydrogene.

Fixed oils do not combine with siliceous earth : With clay, they form a soft paste, which is employed in chemical manipulations, under the name of *fat lute*.

They combine, by particular processes, with magnesia, and are thereby reduced to a saponaceous state.

Lime combines with them, but not in a very discernible manner, when the combination is immediate. Pure alkalis combine easily with fat oils, producing by this combination what is called *soap*.

In making soap, oil of olives or sweet almonds is triturated with a concentrated lixivium of soda, rendered caustic by lime ; and this preparation is known by the name of *soap-lye*.—In the course of a few days, the mix-

ture becomes thick, and forms medicinal soap. Common soap is prepared by boiling the lixivium with altered oil; it is then white. Green soap is made up of the refuse of olives and potash.

Soap dissolves in pure water: Heat decomposes it, disengaging from it phlegm, oil, and ammoniac, formed in consequence of the decomposition of the fixed alkali and the oil; the coaly residue contains a good deal of fixed alkali. This artificial composition of ammoniac seems to prove, that there is azote in the fixed alkali, which re-acts upon the hydrogen of the oil.

Lime-water decomposes soap, as has been remarked by M. Thouvenel; an insoluble calcareous soap is then formed, and deposited in small lumps. Acids, poured on soap, disengage the oil, somewhat altered.

Ammoniac does not easily combine with fixed oils: however, by long trituration, the mixture acquires some degree of consistency, and becomes opaque.

Fixed oils combine with weak acids to form peculiar soaps. Messrs Achard, Cornette, and Macquer, have examined these compounds. M. Achard formed them by pouring slowly a quantity of concentrated sulphuric acid upon the fixed oil. By continued trituration, this mixture is formed into a brown mass, soluble in water and alcohol. The oil obtained from it by the intervention of alkalis, is always more or less concrete, as well as that obtained by distillation. Macquer advises to prepare this soap by pouring acid on the oil; but he informs us, that an acid soap, formed in this manner, is scarce soluble in water; that which is prepared of concentrated sulphuric acid, triturated with common alkaline soap, is more soluble. The concentrated sulphuric

phuric acid blackens fixed oils, and assimilates them to bitumens. This phenomenon seems to be produced by the re-action of the hydrogen of the oil on the oxygen of the acid.

The fuming nitrous acid blackens fixed oils instantaneously, and causes such as are of a dry nature to kindle and emit a flame. Those, again, which cannot be so readily dried, require to kindle them a mixture of this acid with the acid of sulphur, as has been shown by Rouelle the elder, in his *Memoir on the Inflammation of Oils. Academy, year 1747.*

The muriatic and the carbonic acids act with but little strength on fixed oils.—The former of these, however, in a concentrated state, combines with them to a certain degree, according to M. Cornette. The oxygenated muriatic acid thickens them a good deal, and seems to make them pass, by the absorption of its oxygen, into a state in which they bear a great resemblance to wax.

We know nothing of the action of the other acids on fixed oils. It appears that they do not combine with neutral salts. Several of these, and especially all calcareous salts, decompose alkaline soap. In this instance of decomposition, particularly when sulphate of lime, or of magnesia, which is often found in union with waters, decomposes this soap, the sulphuric acid combines with the fixed alkali of the soap, and thereby forms sulphate of soda; the lime or magnesia combines with the oil, and produces a sort of soap that is scarce soluble, and swims in whitish lumps on the surface of the water. This is the cause of the common appearance produced by hard waters, which curdle soap, but do not dissolve it.

The action of hydrogenous gas on fixed oils has not yet been examined.

These oils dissolve sulphur, when their action is assisted by a boiling heat. The solution is of a dark red colour, inclining to brown. It has a very foetid smell. It deposits, by degrees, sulphur in crystals. On distilling this combination, the sulphur is volatilized, being so completely dissolved in the hydrogenous gas that is disengaged from the oil, that not an atom of it is to be afterwards found. This fact deserves to be more particularly inquired into. There is also a little sulphureous gas obtained by this decomposition.

Fixed oils seem not to be susceptible of combination with pure metallic substances, excepting iron and copper, upon which they act in a sufficiently distinct manner. But they combine with metallic oxides, and form with them thick concrete combinations, of a soapy appearance, as is observable in the preparation of unguents and plasters. These preparations have not been yet chemically examined: only we know, that some metallic oxides are reduced in the making up of plasters; as, for instance, oxide of copper in the Divine Plaster, and litharge, or oxide of lead, in the ointment *de la mere*. In the assaying of metals, fixed oils are employed to reduce the metallic oxides. M. Berthollet has given an ingenious and simple process for effecting instantaneously a real combination between fixed oil and any metallic oxide, that is, for preparing a metallic soap. It consists in pouring a metallic solution into a solution of common soap. The acid of the metallic solution combines with the fixed alkali of the soap; and the metallic oxide is then precipitated in union with the oil, to which it

communicates a colour. In this manner, soap of a beautiful green colour may be prepared with sulphate of copper; and with sulphate of iron, a clear deep brown soap. These compounds might be very useful in painting.

Scheele has discovered, that when oil of sweet almonds, olives, rapeseed, or lintseed, is combined with oxide of lead, with the addition of a little water, there is a matter separated from the oil, which swims on the surface of the liquor, and to which he has given the name of *the mild principle*. On evaporating this supernatant water, the principle dissolved in it causes it to take the consistency of syrup; when exposed to a strong heat, it takes fire: one part is volatilized, in distillation, without burning: the coal which it leaves is light: it does not crystallize; nor does it seem to be susceptible of fermentation. Nitric acid distilled on this matter, four times successively, changes it into oxalic acid. This mild principle of Scheele's appears to be a sort of mucilage.

Fixed oils dissolve bitumens, particularly amber; but they must be assisted by the action of heat, in order to effect this solution. They form a sort of greasy varnish, which does not readily become dry.

Fat oils may be distinguished into three genera:

To the *first* class belong such pure fixed oils as are fixed by cold, are slowly thickened, form soaps with acids, and are kindled only by a mixture of the acids of sulphur and of nitre. Such are,

1. Oil of olives, obtained by bruising that fruit between two millstones, and pressing it in bags made of rushes. That which runs first is called *virgin oil*; that which

which is obtained from mark sprinkled with water is not so pure, and deposits a lee; that obtained from unripe olives, is the *oleum omphacinum* of the ancients. Oil of olives freezes at 10° degrees under Zero in Reaumur's thermometer, or $10\frac{1}{2}$ above that point in Fahrenheit's, and will stand about twelve years without becoming rancid.

2. Oil of sweet almonds, extracted without the application of heat, becomes very soon rancid: it freezes at 6° under 0 in Reaumur's scale, or $17\frac{1}{2}$ of Fahrenheit's.

3. Oil of rapseed, obtained from the seed of a kind of cabbage called *colfa*.

4. Oil of ben, extracted from the ben-nut of Egypt and Arabia. It is very acrid, and destitute of smell. It freezes very easily.

The second genus comprehends oils subject to become dry, which are very easily rendered thick, are not fixed by the action of cold, are kindled by the nitrous acid alone, and form, with sulphuric acid, a sort of resin, Such are,

1. Lintseed-oil, obtained by pressure from lintseed roasted. It is used for oily varnishes, and in painting.

2. Oil of nuts, applied to the same uses.

3. Oil of carnations, or poppy seed; which, as has been fully proved by the Abbé Rozier, is not at all narcotic.

4. Oil of hempseed, which is very drying.

Under the third genus, we comprehend concrete fixed oils, or *vegetable butters*; among which we may distinguish the following:

1. Butter of cacao, extracted from the cacao-nut.—There are four sorts of cacao; the large and the small caracca, the berbice, and that of the Islands. This butter is extracted from the nut boiling in water; it is purified by melting it by a very moderate heat.

2. The coco affords a similar butter.

3. Vegetable wax is of the same nature, only more solid. It is the production of China. It is there made into yellow, white, or green candles, the colour varying with the manner in which the wax is extracted. The catkins of birch and poplar afford a small quantity of a similar wax.—That of Louisiana is more plenteous. M. Berthollet easily whitens it with oxygenated muriatic acid.

Fixed oils are much used in the arts, and in medicine, and are applied to various purposes. In the latter they are used as softening, relaxing, calming, and laxative medicines. Some of them are even purgative; as, for instance, the *Oleum Ricini*, which has been found to destroy the tænia, or solitary worm, and cause it to be evacuated. They enter into a great many compound medicines, such as balsams, unguents, and plasters.—Lastly, they are sometimes used as seasoning, or food, on account of their agreeable taste, and the mucilage which they contain.

C H A P. X.

Of Volatile Oils.

VOLATILE or *essential* oils are distinguished from fixed oils by the following peculiar properties.— Their smell is strong and aromatic; They are so volatile, that they may be distilled by the heat of boiling water: Their taste is very acrid: They are much more combustible than the other class of oils.

These oils are found to exist in almost all odorous plants. They are contained either in the whole plant, as in the angelica of Bohemia, or only in the root of the plant, as in starwort, the iris, white dittany, and kidney; or in the stem, as in sandal, saffrafras, and pine-wood; or in the bark, as in cinnamon. Sometimes it is confined to the leaves, as in balm, peppermint, worm-wood, &c. In other plants, it is found in the calices of the flowers: Of this kind are the rose and lavender; the petals of camomile and the orange-flower are filled with it. It is, at other times, fixed in the fruits, as in cubebs, pepper, and juniper-berries. Lastly, A number
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of vegetables contain it in the seed ; such as nutmeg, anise, fennel, and the many umbelliferous plants.

These oils differ from one another, 1. In their quantity, which varies according to the state or age of the plant : 2. In consistency ; some are very fluid, such as those of lavender, rue, &c. ; some congeal by cold, such as oil of anise, and fennel ; others are always concrete, of which kind are the oils of roses, parsley, kidney-wort, and star-wort : 3. In colour ; some are destitute of colour ; others, such as oil of lavender, are of a pale yellow ; or a dark yellow, as oil of cinnamon ; or blue, as oil of camomile ; or sea-green, as oil of St John's-wort ; or green, as oil of parsley : 4. In gravity ; some swim on the surface of water, most of those, indeed, that are produced in temperate countries ; others sink to the bottom of that fluid, as oil of saffraas, of carraway-seeds, and most oils of this kind from hot countries ; this property, however, is not constant with respect to climate, for the essential oils of pepper, nutmegs, and mace, &c. are lighter than water : 5. In taste and smell ; the taste of an essential oil is often very different from that of the plant from which it was extracted ; pepper, for instance, affords, a mild oil, and oil of wormwood is not bitter.

Volatile oils are extracted, 1. By pressure, from codra, bergamot, lemons, oranges, &c. ; this is called *essence* : 2. By distillation ; the plant is put into the cucurbit of a copper alembic, with water ; the water is boiled, and the oil passes together with the fluid, and gathers above it in a receiver prepared for their reception.

Volatile oils are adulterated either by fixed oils, which is detected by their staining paper ; or by oil of turpentine,

penting, which may be discovered by the strong smell peculiar to turpentine, which always remains after the essential oil is evaporated; or by alcohol, and then water, by rendering the mixture turbid, detects the alteration produced by this substance.

Volatile oils lose their smell by a moderate heat. As they are so very volatile, fire does not decompose them. When heated in close vessels, they give out a large proportion of hydrogenous gas. When heated in contact with air, they take fire speedily, and exhale a very thick smoke, which is condensed into a very fine, light, carbonaceous matter: They leave but very little coaly residue after inflammation, being so volatile, that the carbonaceous matter is carried off along with the part that is volatilized.

- When exposed to the air, they become thick, and, in process of time, are converted into resins. They deposit needled crystals, like those of sublimated camphire. Geoffroy the younger observed these crystals in the volatile oils of mother-wort, marjoram, and turpentine. Their smell, he informs us, is much the same with that of camphire. *Acad.* 1721, page 163.

They combine with some difficulty with lime and alkalis; and form with these substances imperfect soaps, to which we give the name of *saponulæ*: Acids alter them; the concentrated sulphuric acid changes them into bitumens; when weak, it forms with them a sort of soap. The nitrous acid inflames them; the muriatic acid reduces them to a saponaceous state; the oxygenated muriatic acid thickens them.

They act not upon neutral salts.

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They combine very easily with sulphur, with which they form compounds that are called *balsams of sulphur*, in which the sulphur is so divided that it cannot be extracted, but is separated by heat in the form of sulphurated hydrogenous gas.

Mucilages and sugar render them soluble in water. They are used in medicine as cordials, stimulants, antispasmodics, &c. Externally applied, they are powerful antiseptics, and stop the progress of caries in the bones.

C H A P. VIII.

Of the Camphorate Principle.

CAMPHOR is a white matter, concrete, crystalline, and of a strong taste and smell ; in some of its properties nearly allied to volatile oils, but widely distinguished from them by others.

Chemists have, from a great variety of observations, concluded camphor to be an immediate principle of vegetables, which, they think, exists in all highly odorous plants that contain volatile oil. It has, in fact, been obtained from the roots of the cinnamon tree, zedoary, thyme, rosemary, sage, and many other labiated plants, either by distillation or decoction, as has been observed by Cartheuser and Neumann. But the quantity of the camphor thus obtained is very small, and it always retains a smell of the plant from which it was extracted. This singular substance appears to be combined with the volatile oils of these vegetables, as those oils have been observed by Geoffroy to deposit needles of camphor. I have seen, in the possession of M. Josse, apothecary at
Paris,

Paris, true camphor extracted from the root of elecampane. Lorry thought camphor a very general principle in vegetables, and placed its aromatic flavour at the head of a class of very powerful odours, the effects of which on the animal œconomy well merit the attention of physicians. M. Proust has published a Dissertation, in which he describes a process for obtaining camphor in considerable quantity from the oils of several aromatic plants that grow in Mureil.

The camphor used in medicine is extracted from a sort of bay-tree that grows in China, Japan, and in the isles of Borneo, Sumatra, Ceylon, &c. The tree which produces it, often contains it in such abundance, that very large and pure tears of camphor may be obtained from it solely by splitting the wood. It is commonly; however, extracted by distillation. The roots, or other parts of the tree, are put into an iron alembic, with water, covered over with a capital, containing ropes of rice-straw, and thus exposed to heat. The camphor is sublimated in small greyish grains; and these again unite into larger pieces. This crude camphor is impure. The Dutch purify it by sublimating it in a sort of balloon, and adding an ounce of lime to the pound of crude camphor.

Camphor is much more volatile than the essential oils; for the gentlest heat is sufficient to sublime it. It crystallizes in hexagonal plates, with a stem in the middle. When a strong heat is applied, it melts before volatilizing. It does not appear to be decomposable by this means: however, when distilled a number of times successively, it affords a reddish phlegm, evidently of an acid nature; and this shews, that if the process

were carried farther, its nature might at length be altered. The temperature of summer is sufficient to volatilize camphor. When exposed to the air, it is entirely dissipated and lost; when inclosed in close vessels, it is sublimated in hexagonal pyramids, or in polygon crystals, which were, in the year 1756, observed and described by Romieu. It exhales a strong smell, too strong indeed for the nerves of some people to bear. It takes fire very easily, burns with a good deal of smoke, and leaves no coaly residue.

It is not soluble in water; it will, however, communicate its smell to water: it burns on its surface. Romieu has observed, that small pieces of camphor, one third, or one fourth of a line in diameter, when put into a glass of pure water, move round, till they are at length dissolved in about the space of half an hour. He suspects this motion to be an effect of electricity; and observes, that it ceases when the water is touched with any body that can act the part of a conductor, such as iron-wire; and that, on the contrary, it still continues, though the water be touched with an insulating body, such as glass, resin, sulphur, &c.

Earths, salino-terrene substances, and alkalis, are incapable of acting on camphor. We must observe, however, that the power of caustic alkalis on this substance, has not yet been brought to trial.

Acids, when concentrated, dissolve camphor. The sulphuric acid dissolves it, with the help of heat: the solution is red. The nitric acid dissolves it slowly: this solution is yellow. As it swims over the acid in the same way as oils, it has been improperly called *oil of camphor*. M. Kosegarten has discovered, as has been
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taken notice of in the VIIth Chapter, that the nitric acid, when distilled eight times successively upon camphor, changes into a crystallizable acid, which he thinks to be of a peculiar nature.

The muriatic acid gas dissolves camphor; so likewise do the sulphureous acid gas, and the fluoric acid gas. When water is poured into these solutions, they become turbid; the camphor is separated in flakes, which swim on the surface of the liquor, and appear to have suffered no alteration. Alkalis, the salino-terreæ substances, and metallic matters likewise precipitate these solutions.

Neutral salts act not upon camphor. We know not in what manner sulphur and bitumens act upon this substance; but they are probably capable of combining with it.

The fixed and the volatile oils dissolve camphor with the help of heat. These solutions, when cooled, deposit, by degrees, crystals in a vegetative form, similar to those that are formed in solutions of ammoniacal muriate; that is, consisting of a stalk, with very fine filaments extending from it horizontally. These filaments, which in their disposition resemble the beard of a feather, exhibit a very beautiful and regular appearance, when viewed through a microscope. We owe this fine fact to Romieu, (*Academy 1756, page 448.*) The solution of camphor in alcohol, which is much better known, and much more in use than the preceding solution, was observed by the same chemist to afford, by a particular process, a species of crystallization somewhat different.

Camphor is one of the most potent remedies which medicine employs. It dispels inflammatory tumours in a

very short time. It is used as an antispasmodic and antiseptic medicine, in infectious distempers, the malignant fever, and all diseases in general that are attended with affections of the nerves and putridity. In France, it is given only in doses of a few grains: In England and Germany, they go so far as to give it in doses of several drachms a-day. It is also worthy of being mentioned, that camphor alleviates burnings, and pains in the urinary passages, so speedily often as might tempt the patient to think his relief the effect of enchantment. It is given either triturated with the yolks of eggs, sugar, and gums, or in the state of oil of camphor, and always in certain drinks prepared for the purpose. Surgeons apply camphorated spirit of wine, of the composition of which we shall hereafter give an account, to external gangrenes; and the liquor often puts a stop to their progress.

C H A P. XII.

Of the Spiritus Rector, or the Aromatic Principle of Plants.

BOERHAAVE gives the name of *spiritus rector* to that principle to which plants owe their smell: very little, however, is as yet known concerning the properties of this singular substance, which, from its influence on the animal œconomy, so strongly attracts our notice. We use the name *aroma*, instead of *spiritus rector*, deriving it from the well-known term *aromatic*.

The aromatic principle of plants appears to be very volatile, very fugitive, and very subtle; it is continually disengaged from plants, forming around them an odorous atmosphere, of a wider or a narrower extent. Plants differ all from one another in the quantity, the strength, and the nature of their aromatic principle. Some are plenteously provided with this principle, and lose it only in part when dried, so that it would appear to be in some measure fixed in them: of this kind are ir.

general all odorous woods, and all the dry and ligneous odorate parts of vegetables. In others, this principle is so fugitive and volatile, that though they be strongly odorous, they can scarce be rendered permanently so. Lastly, there are some plants which possess the odorous principle in so low a degree, that they are said to be inodorous, and their *aroma* has been distinguished as *herbaceous*.

The slightest degree of heat is sufficient to disengage the aroma of plants. To obtain it, the plant must be distilled in a *balneum-mariae*, and its vapours received into a cold capital, which may condense, and conduct them in a fluid state into the receiver. The product is pure odoriferous water, and is known by the name of essential or distilled water. This liquor is to be considered as a solution of the odorous principle in water. That principle is more volatile than the water in which it is dissolved. This aromatic water, when heated, loses by degrees all its smell, and becomes insipid. It suffers the same alteration when exposed to air; it then deposits very light flakes, of a mucilaginous appearance, and acquires a smell of mouldiness.

The principle of smell combines with oily juices; and even appears to constitute one of the elementary principles of volatile oils; for, 1. These oils are always impregnated with it: 2. Those plants in which the principle of smell is considerably fixed, afford invariably more volatile oil than those of which the smell is very fugitive; many of which, as, for instance, those of the lily kind, often afford no volatile oil at all. The aroma of this latter class of plants, such as the tuberose and the odoriferous lily, needs to be combined with fixed oils,

oils, in order to prevent its escape. The jasmine, too, is of the same character. The flowers of these plants are put into a tin cucurbite with cotton, moistened with oil of ben; the flowers and the cotton are disposed in alternate layers; the cucurbite is then shut, and exposed to a gentle heat: The aroma, disengaged from the flowers, then combines with the oil, so as to become permanently fixed. 3. Plants that have no smell, never afford a single particle of volatile oil. 4. Vegetables, from which aromatic water has been extracted by distillation on the *balneum-mariæ*, no longer afford any volatile oil; at least, unless they still retain some little smell; and even in that case they afford but a very small quantity of oil. 5. Volatile oil that has lost its smell, readily regains it with all its properties, when distilled with a fresh plant of the same species with those from which it was at first extracted.

The action of saline matters on aromatic water has not yet been examined. M. Berthollet has discovered, that the oxygenated muriatic acid often destroys the smell of vegetables, and of consequence alters their aroma. It has of late been used to determine the degree or intensity of the aroma of several substances that are used as perfumes.

The nature of this principle is not the same in all plants; it varies according to the genera of the plants to which it belongs. Macquer follows Boerhaave in thinking, that it is generally a compound of an inflammable substance with a saline matter; but observes, that it sometimes partakes more of a saline nature, and at other times approaches nearer in nature to oily matters. The aroma of cruciform plants, he thinks to be
saline;

saline ; and ascribes to it to the characteristics of being pungent and penetrating, yet not affecting the nerves : That, again, which is insipid, or strong, but not pungent, and affects the nerves, so as either to occasion, or to mitigate, fits owing to the particular state of the nervous system,—effects which aromatic and narcotic plants usually produce ;—that, according to this celebrated chemist, has more of an oily than of a saline nature. Several facts concur to support this opinion. The *fraxinella* diffuses an odour which forms an inflammable atmosphere around it ; and whenever a burning body comes within this atmosphere, it takes fire ; and the vapour then burns from the lower to the upper part of the stem that supports the flowers.

The aroma of the *fraxinella* seems therefore to be of an oily nature. Venel, a chemist at Montpellier, who studied under Rouelle, extracted an acid *spiritus rectior* from favoy (marum) by a gentle heat ; and Roux, professor of chemistry in the schools of medicine, having examined the product, found that it did not redden vegetable colours, but saturated alkalis. With respect to the aroma of cruciform plants, chemists are not yet agreed concerning its nature. Some think it acid ; others call it alkaline. It appears from the experiments of Messrs Deyeux and Baumé, that sulphur is found in combination with the odorate principle of antiscorbutic plants ; and that it is this combustible body, reduced to the state of elastic fluidity, by combination with hydrogen, which constitutes the aroma of cruciform plants.

There are yet two important observations to be made concerning the aroma of plants. In the first place, it is perhaps, as Macquer suspected, a gas of a peculiar nature :

ture : its invisibility, its volatility, the manner in which it diffuses itself through the atmosphere, its power of expansion, together with some experiments by Dr Ingenhoufz on the noxious gas exhaled from flowers, render this opinion highly probable.—What we want to determine this point, is a series of experiments, which would indeed require to be performed with the utmost care and accuracy, but would certainly accomplish some noble and useful discoveries. Boyle has already opened a wide field of inquiry concerning smells, their alterability and reciprocal combination : and that train of research has been very successfully prosecuted by Lorry. This philosopher has observed the alterations produced on them by mixture with one another, by fermentation, and by the action of fire, air, and different menstrua.—We cannot, without making an improper digression, enter here into a particular detail of his experiments ; but we may mention his general division of smells. Lorry divides these bodies into five classes, camphorate, æthereal, poisonous, or narcotic, acid, and alkaline : All smells may, in his opinion, be referred to some one of these classes. In explaining the grounds on which he establishes this division, founded on the manner in which smells affect the sense of smelling, and the nerves in general, Lorry informs us, that he proposes not to examine their chemical nature : But it is probable, as he himself thinks, that those of each class are nearly of the same nature in respect to chemical properties, as well as to the manner in which they affect the animal œconomy.

Our second observation, and with it we mean to conclude the chemical history of the principle of smell, is, that though the plants which have been called inodo-

rous,

rous, be thought to contain none of this principle ; yet is it at present a well known fact, that, by the gentlest heat of a *balneum-mariæ*, there may be extracted from them a water, of which the smell, though very faint, will however be sufficient to indicate from what plant it was extracted.—I can assert this upon my own experience. I have often found those plants that are commonly reckoned the most inodorous, such as succory, plantain, borage, &c. to afford, by the *balneum-mariæ*, a water that diffuses a smell, by which the nature of the plant from which it was extracted may be sufficiently known. It is true, that these insipid aromatic waters are very soon decomposed, and lose, in a short time, that faint smell by which they are distinguished : They are altered, and ferment, and pass either into an acid or an alkaline state.

The perfumer's art is founded on the method of extracting the odorous parts of vegetables, of preserving, and of fixing them in different substances. Most of the processes of that art are entirely chemical.

Medicine, too, makes much use of distilled or aromatic waters. They possess different virtues, according to the peculiar nature of each. Those employed for the purposes of medicine are usually distilled by naked fire, with water, in the same way as volatile oils. This manipulation answers very well for the aroma of such waters as are truly aromatic, but not so well with those plants that are commonly called inodorous. These ought to be distilled in a *balneum-mariæ* ; and as this precaution is seldom taken, they have usually an empyreumatic smell, acquired from the fire, even when not impregnated with the odorous principle of the plant.—If these waters owe all their virtue to the aroma which they contain, weak as

that

that is, it is certain that the mode of preparing them destroys all the properties which that principle can possibly confer upon them.

To these observations we shall only add, that the distilled waters of plants prepared by the apothecary, are not that pure aroma which Boerhaave called *spiritus rectior*, but that principle, diluted in a large proportion of water, distilled with the plants.

C H A P.

CHAP. XIII.

Of Resinous Inflammable Juices in general, and of Balsams in particular.

THE name *Resins* is given to certain dry inflammable matters, which cannot be mixed with water, but are soluble in oils and alcohol, and run fluid from the trees in which they are produced. These matters are nothing but oils concreted by the desiccative action of the air. Various opinions are entertained concerning the difference between balsams and resins. Some give the name of balsams to inflammable fluid substances; but there are also dry balsams: Others, confine the name to the most odorous inflammable substances. Bucquet has thrown much new light on this matter, by confining the name of *balsams* to such of those combustible matters as are sweet-smelling, and can communicate their smell to water: and especially, which contain odorate and concrete acid salts,

alts, that may be obtained from them by sublimation, or decoction in water.

The principal species of balsams are the three following:

1. Benzoin. Of this there are two sorts: the amygdaline benzoin, in white tears resembling almonds, united by a brown juice; and common benzoin, of a brown colour, not in tears: it exhales a very pleasing smell, when melted or pricked with a hot needle. The tree that affords it is but little known. Linnæus, he son, calls it *terminalia benzoin*. Murray observes, that the wood and the bark of this tree diffuse an odour of benzoin whilst burning. The same author thinks it doubtful, however, whether it affords this balsam or not. This balsam comes to us from the kingdom of Siam, and the island of Sumatra. On account of its solidity, it affords but little essential oil. Boiling water extracts from it an acid salt in needles, which is strong smelling, and crystallizes by cooling. The salt is also obtained by sublimation. When obtained by this last process, it is called *flowers of benzoin*. This operation is performed in two varnished earthen pots, placed one above the other, and made close with paper at the place of their junction. The fire must be moderate, otherwise the salt becomes brown. The pasteboard cone which was formerly used for this purpose suffered a great deal of the concrete acid to escape. We have given an account of the properties of this acid in a preceding chapter. Benzoin affords, in a retort, a very acid phlegm, a concrete brown salt of the same nature, and

and brown thick oil : the residual coal contains fixed alkali.

Benzoin is soluble in alcohol ; and the tincture of this balsamic substance, precipitated by water, forms *lac virginale*. Salt of benzoin is used as a good incisive in pituitous disorders of the lungs and reins. The oil is discutient, and is externally applied to limbs affected with palsy, &c.

2. Balsam of Tolu, Peru, and Carthagena. This balsam is brought to Europe, either in cocoa-nut-shells, or in yellowish tears, or in a fluid state : it flows from the *toluifera*, which Linnæus ranks in the decandria monogynia class. It may be extracted from the shells by steeping them in boiling water, which renders it fluid. It comes from a country in South America, situated between Carthagena and Nombre de Dios, called by the inhabitants of the islands Tolu, and by the Spaniards Honduras. It affords, when analysed, the same products as benzoin, and especially a concrete acid salt. It is made into syrup, and administered in diseases of the lungs.

The acid of the balsam of Tolu has not been yet examined : it is thought not to differ essentially from the benzoic acid.

3. Storax calamita is in tears, either red and clean, or brown and greasy. It smells very strong ; it runs from the oriental liquid ambar, a plant that is but little known. Duhamel observed a juice running from the *alibouffer*, that had nearly the same smell. Neumann analysed the storax calamita, and obtained from it an essential oil, a concrete acid salt, and a thick oil. It serves for nearly the same purposes as benzoin ;

benzoin : it is chiefly used for perfume. We formerly had it sent to us in reeds ; but we now get it in loaves, or irregular masses, of a reddish brown colour, mixed with a few tears of a lighter colour, and a more pleasant smell.

C H A P. XIV.

Of Refins.

RESINS differ from balsams, as having a less pleasing smell; and, still more eminently, as containing no concrete acid salt. The following are the principal species of resins.

1. Balsam of Mecca, Judæa, Egypt, Grand Cairo. It is liquid, white, bitter, and of an high lemon-colour. It runs from a tree that is called *amyris opobalsamum*, ranked by Linnæus in the octandria monogynia, and discovered in Arabia the Happy by M. Forskahl. This liquid resin affords a great deal of essential oil by distillation. With sugar, and yolks of eggs, &c. it is used as a vulnerary.

2. Brown or yellow balsam of Copahu, which runs from the tree called *copaiba*, and by Linnæus *copaifera*, and ranked by that botanist in the decandria monogynia. The common kind, both of this and of the balsam of Tolu, is, according to Cartheuser, a mixture of
genuine

genuine balsam of Copahu with turpentine. It is used, as well as the preceding resin, as a remedy for ulcers of the lungs and bladder.

3. Chio turpentine runs from the turpentine-tree that bears the pistachio-nuts. It is of a white or yellow colour, inclining to blue. It affords, on a *balneum-mariæ*, a very fluid volatile oil : that which it affords by naked fire is not so fluid. The turpentine is, after this operation, of a still yellower colour. When distilled with water, it is white and silky, and is called *boiled turpentine*. This turpentine is not common, and is not applied to any use.

4. Venetian turpentine, or Milesian resin, is that most commonly used in medicine. It is used either in its natural state, or combined with fixed alkali. This composition has been called *Starkey soap*. We consider it as a *saponula*. To prepare it, the Paris Dispensary directs to pour four ounces of volatile oil of turpentine on half a pound of nitre fixed by tartar, and still hot ; to stir the mixture with an ivory spatula, and cover the vessel with a piece of paper ; adding oil, by degrees, till the whole form one white mass. This process takes up several months ; and chemists have therefore sought to find out some more expeditious method of making up the medicine. Rouelle prepared, in the space of three hours, a pretty considerable quantity of this soap, by triturating alkali with the oil dropped upon it, and adding a little water towards the end of the operation. M. Baumé directs to levigate upon porphyry one part of alkali of tartar, previously exposed to heat till it shall have been brought near the point of fusion ; and to add to it, by

degrees, two or three times its weight of volatile oil. When the mixture is brought to the consistency of a soft opiate, put it into a glass-cucurbit, covered with paper, and set it aside in a damp place. In fifteen days time, the deliquescent alkali forms a distinct portion of liquor at the bottom of the vessel; the soap occupies the middle; and a portion of the oil, having assumed a red colour, swims on the surface. M. Baumé thinks that the alkali unites only with that portion of the oil which is in a resinous state. M. le Gendre pursues this idea farther, and proposes to saturate a cold solution of the fixed alkali with concentrated oil of turpentine, or even with turpentine itself. This soap is in some degree solid, and becomes gradually more so: crystals are formed in it, which have been considered as a combination of the acid of the oil with vegetable fixed alkali. But, according to the academicians of Dijon, they are nothing but potash saturated with carbonic acid, and crystallized in that state. As it is no easy matter to make up this soap, and it is, besides, very liable to alteration, Macquer thinks, that when a substance is wanted, possessing the properties of volatile oils, and those of soaps, in union, it were better on any occasion to incorporate a few drops of volatile oil with medicinal white soap, to serve the present purpose. Ammoniac, triturated with turpentine, forms a solid saponaceous compound, which dissolves very readily with water, and renders it milky and frothy.

5. The resin of the fir-tree is called turpentine of Strasburg. It is obtained by piercing the vesiculæ of
the

the bark of the fir-tree, of which there are extensive forests on the hills of Switzerland.

6. Pitch is the juice of a sort of a fir-tree, called *abies picea*. It is obtained, by incision, from the bark of the tree. It is melted by a moderate fire, pressed in bags of cloth, and received into barrels: This is Burgundy pitch, or white pitch; by mixture with lamp-black, it is converted into black pitch. When it is kept long in fusion with vinegar, it becomes dry and brown, and so forms what is called *Colophony*. The more impure parts are burnt in a furnace, with a chimney passing into a small cabinet, terminating in a cone of cloth: the smoke is condensed in this cone, into a fine soot, that is called *lamp-black*.

7. The galipot is the resin of the pine which bears the soft apples. This tree is notched towards the bottom, and the resin runs out into troughs. When the resin ceases to run out by the lower holes, they are continued upon the tree. When it runs fluid, it is called *galipot*; that which hardens upon the tree into yellowish masses, is called *Barras*. These juices are liquified in boilers; and after being concentrated by heat, are filtrated through straw-mats, and run into moulds in sand, or formed into loaves that are called *arcançon*, or *bray-sec*. When water is poured in, the matter becomes white, and forms *resin*, or *pitch-resin*. The inhabitants of Provence distil galipot: they extract from it an oil which they call *huile de raze*. *Tar*, which is the empyreumatic oil of this substance, is prepared from the trunk and roots of the pipe. A quantity of the wood is heaped together, covered with

turf, and set on fire. The turf hinders the oil that is disengaged by the heat from being volatilized; and it passes into a shallow tub through a channel, out of which it is removed, without farther preparation, to be sold as *tar*.

8. Tacamahaca, gum elemi, *gum animæ*, are very little used. The tree that affords the first is unknown. The *elemi* is produced by a species of *amyris*. The oriental gum animæ, or copal, the origin of which is unknown, and the occidental gum animæ, or *courbaril*, which flows from the *hymenæa*, a tree that grows in South America, are used for varnishes.

9. Mastic is in white, farinaceous tears, of a faint smell: It flows from the turpentine tree, and the mastic tree; it is used as an astringent, and an aromatic; it enters into the composition of drying varnishes.

10. Sandarac is in white tears, more transparent than those of mastic. It is obtained from the juniper-tree, in which it occupies a place between the bark and the wood. It is likewise called *varnish*, as it enters into those preparations. It is used, in powder, to prevent ink from sinking on paper, from which the external coating of size has been scraped off.

11. The resin of guayacum, which is greenish, is used as a remedy for the gout. It is obtained, by incision, from the guayacum tree.

12. Labdanum the resin of a species of *cistus* in Candia, is of a blackish colour. The peasants gather it by striking the trees with staves, having a number of leather-thongs fixed to the one end. They make it up into cylindrical pieces, which they call *ladanum in tortis*.

It is adulterated by a copious addition of blackish sand :
It is used as an astringent.

13. Dragon's blood is a red juice, extracted from the *dracena draco*, and some other trees of a similar nature. It comes to us in small flat cakes, or round balls, or in little spherical pieces, wrapped up in leaves, and knotted like a chaplet. It is used in medicine as an astringent.

C H A P. XV.

Of Gum Resins.

GUM RESINS are mixed juices, consisting of resin and extractive matter, which has been taken for a gummy substance. They run by incision, but never naturally, from trees or plants, in the form of white, yellow, or red emulsive fluids, which are sooner or later consolidated. Water, alcohol, wine, vinegar—none of all these liquors dissolves more than a part of gum resins. They differ in the proportions of the resin and the extract, and afford, by analysis, many various results. The following are the most important species :

1. Olibanum consists of yellow transparent tears, of a very strong and disagreeable smell. It is not known from what tree it flows. It affords, by distillation, a small portion of volatile oil, and an acid spirit, leaving a pretty large residual coal, produced from the extractive matter which it contains. It is used in fumigations as a resolvent medicine.

2. Galbanum is a fat juice, of a brown-yellow colour,
and

and a nauseous smell. It runs, in Arabia, Syria, and at the Cape of Good Hope, from incisions in a ferulaceous plant, called *Bubon Galbanum* by Linnæus. When distilled by naked fire, it affords a blue essential oil, which afterwards becomes red, an acid spirit, and a ponderous empyreumatic oil. It is an excellent discutient, and a powerful antispasmodic.

3. Scammony is of a blackish grey colour, a strong nauseous smell, and a bitter and very acrid taste. The scammony of Aleppo is by far the purest. That of Smyrna is ponderous, black, and mixed with extraneous bodies. It is extracted from the *convolvulus scammonia* of Linnæus. The root of the plant, cut and squeezed, affords a white juice, which, when dried, becomes black. The various specimens of scammony contain various proportions of extract and resin; on which account its effects as a medicine are far from uniform. It is given as a purgative, in dozes of from four to twelve grains. Mixed with a sweet extract, such as that of liquorice, it forms the common *diagredium*. It is likewise used for this purpose with the juice of quinces. It is usually given in a powder with sugar and sweet almonds.

4. Gum guttæ is yellow, reddish, destitute of smell, and of a strong, acrid, and corrosive taste. It comes from Siam, China, and the island of Ceylon. It is extracted from a large tree, very little known to us, and distinguished in the countries where it grows by the name of *Coddam Pulli*. It contains a good deal of resin, which renders it strongly purgative, when administered in dozes of four or six grains. It should be very cautiously administered internally.

5. Euphorbium is in yellow tears, which are of a carious or worm-eaten appearance, and have no smell. It runs from incisions in the plant *euphorbium*, which grows in Ethiopia, Lybia, and Mauritania. It contains a very acrid resin. It is so strongly purgative, as to be ranked among poisons. The only medical use for which it serves, is in external applications to caries.

6. *Asa-fetida* is sometimes in yellowish tears, but ofteneft in loaves, confifting of different pieces agglutinated together. It has a very foetid fmell of garlic, and tastes bitter, and naufeoufly difagreeable. It is extracted from the root of a fort of *ferula* that grows in the province of Chorazan in Perfia, and has been called by Linnaeus *Asa-fetida*. The root of this plant is fleshy and succulent. It affords, by expreffion, a white juice, of an abominable fmell, ufed by the Indians as a seasoning, and called by them *food for the Gods*. It is ufed internally as a powerful antispasmodic, and externally as a difcuffive.

7. Aloes is a juice of a dark red, and sometimes even a brown colour, with confiderable bitternefs of taste. There are three kinds of it: socotorine aloes, hepatic aloes, and caballine aloes. The first is the pureft; and it is only in purity the three forts differ. A. de Juffieu faw thefe feveral kinds of aloes prepared at Morviedro, in Spain, from the leaves of the common aloes. Deep incisions were made in the leaf; the juice ran out by thefe: It was then decanted from above the *fæcula*, and thickened by expofure to the fun. The aloes prepared in this manner is put up in leather-bags, and fold under the name of socotorine aloes. The juice squeezed from the leaves, purified by rest, and then dried, forms
hepatic

hepatic aloes. Lastly, The leaves are again pressed; and the juice now obtained from them, mixed with the lees remaining from the two former operations, forms cabal-line aloes. The first of these different sorts of aloes contains much less resinous matter than either of the two latter, and is therefore much less purgative. It is used in medicine as a drastic purge, and is known to possess the property of bringing on the menstrual flux with women, and the hæmorrhoidal flux with men. It is recommended as an excellent hydragogue.

8. Myrrh is in the form of reddish tears, of a brilliant appearance, of a pretty strong but agreeable smell, of a bitter taste, and exhibiting in their fracture, when broken, white lines of the form of a nail. Some of these tears are entirely gummy and insipid. Myrrh comes from Egypt, but chiefly from the ancient country of the Troglodytes, in Arabia. The plant that affords it is unknown to us. It contains much more extract than resin. It is used in medicine as a very good stomachic, an antispasmodic, and a cordial. Cartheuser advises literary people, who have delicate stomachs, to chew and swallow it with their spittle. It is used in surgery for cleansing putrid ulcers, and stopping the progress of caries, either in powder, or diluted in spirit of wine.

9. Gum ammoniac sometimes appears in tears that are white internally, but externally yellow, and often in masses much like those of benzoin. They are easily distinguished, however, by their white colour and fœtid smell. This gum resin, which we get from Africa, is thought, on account of the seed mixed with it, to be extracted from an umbiliferous plant. This substance being soluble in water and spirit of wine, as well as inflammable,

is nearly of the same character with those which Rouelle has named resinous extractive matters.

In medicine, gum ammoniac is used as a very good discutitive in cases of obstinate obstruction. It is given in doses of a few grains, either in pills or emulsions: it enters also into the composition of many discutitive and resolvent plasters.

10. Elastic resin, or caout-chouc, is a substance concerning the nature of which it is hard to say any thing. Its containing combustible matter, which is used in America for lights, is a characteristic in which it agrees with resinous substances: but its elasticity, softness, and insolubility in the menstrua, which usually dissolve resins, distinguish it as a substance of a different nature.

The tree which affords it, grows in various parts in America. Large incisions are made through its bark, which must always penetrate to the wood: a white juice, more or less fluid, flows from it, and is received into vessels, in order that it may be applied to the different purposes for which it is suitable: it is laid in layers on clay moulds; and dried by exposure to the sun, or to fire. Various designs are then sketched upon them with the point of an iron instrument: they are then exposed to smoke; and when sufficiently dried, the moulds are broken. In this way are formed the bottles, and other utensils of elastic gum, that come into Europe.

The vessels made of this matter are capable of holding water, and such other fluids as have no power of acting upon it. If it be cut into pieces, and the edges applied to each other soon after they are cut, the pieces unite again. I examined juice of caout-chouc, which was sent me from Madagascar. It was white as milk, and its smell insu-

ferably foetid. It contained a concrete, white, spongy matter, in the middle of the bottle, of a similar form, and likewise elastic. When the liquor was heated, a white pellicle of genuine elastic resin was very soon formed on its surface. Alcohol, mixed with the juice, separated from it flakes of that resin.

When the caout-chouc, in a dry state, such as it is sent into Europe, is exposed to fire, it becomes soft, swells, exhales a foetid odour, and shrinks as it burns.

Elastic resin is not soluble in water. We know not in what manner saline matters act upon this substance. Macquer, after trying to dissolve it in various menstrua, was convinced of what had been before asserted by Messrs de la Condamine and Fresneau, (*Academy, year 1751*), that alcohol was incapable of acting upon it, but that oils dissolved it with the help of heat. However, as he wished to reduce it to a liquid state, so that it might be made use of in that form, and might recover its properties by the evaporation of the solvent liquor, he was obliged to employ another menstruum than oils; because oils, however volatile, always altered the elastic resin, and became fixed in it, so as to weaken its strength, and destroy its elasticity. He at length dissolved this substance in highly rectified æther; and this being so very subject to evaporation, perfectly suited his purpose: (*Academy, year 1768*). And though that liquor be indeed very dear, yet he thought it might be of some consequence to make known to the public a method of making some very useful instruments, such as catheters, by putting, on a waxen mould, successive layers of this solution, till they be of the required thickness. When the catheter is dry, let it be immersed in boiling water,

which, by melting the wax, separates it from the mould. The softness and elasticity of a catheter of this substance, render it the most proper for persons who find it necessary to wear such an instrument constantly.

These are all the particulars of the history of elastic gum that were known to the world before the month of April 1781; at which time M. Berniard, distinguished by the accuracy of his experiments, inserted in the *Journal de Physique* an excellent Memoir on this singular substance. That chemist concludes from his experiments, that elastic resin is a peculiar fat oil, coloured by a matter soluble in alcohol, and contaminated with the soot of the smoke to which each layer of the resin must be exposed, in order to dry it. Water produces no alteration upon it: alcohol, assisted by a boiling heat, discolours it. Caustic fixed alkali is incapable of acting upon it. The concentrated sulphuric acid reduces it to a carbonaceous state, and is itself at the same time tinged with a black colour, and takes the smell and the volatility of the sulphureous acid. The common or weak nitric acid acts on this resin in the same way as on cork, and gives it a yellow colour; the nitric acid, strongly concentrated, decomposes it very rapidly; the muriatic acid produces no sort of alteration upon it; rectified sulphuric æther did not dissolve it: This fact must appear singular, as the author observes, to all those who know the accuracy and veracity of Macquer. Nitric æther did dissolve it. This solution was yellow, and afforded, by evaporation, a transparent substance, friable, and soluble in alcohol;—in a word, a genuine resin, formed, according to this author, by the action of the nitric acid on the elastic caout-chouc. The volatile oils
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of lavender, aspic, and turpentine, dissolved it with the help of a gentle heat ; but they formed clammy fluids, which stuck to the hands, and could not therefore be applied to any useful purpose. A solution of elastic resin by oil of aspic, when mixed with alcohol, deposited white flakes, which were insoluble in hot water, but floated on the surface of that fluid, and became, by cooling, white and solid like wax ; in a word, they formed a genuine, fixed, concrescible oil. Oil of camphor dissolved elastic resin by simple maceration. When the solution was evaporated, the camphor was volatilized ; and there remained in the capsule an amber-coloured matter, of a firm consistency, but scarce gluey, and easily soluble in alcohol. Fixed oils, when boiled upon elastic resin, dissolve it : wax likewise dissolves it. This substance does not melt by a boiling heat ; but when exposed to the action of fire in a silver spoon, it is reduced into a thick black oil : It then exhales white vapours ; after which it remains fat and clammy, though exposed to the air for several months ; nor does it ever again recover its dryness and elasticity, which are so necessary to fit it for the purposes to which it is applied. Lastly, M. Berniard concluded his experiments on this substance, by analysing it by naked fire. From an ounce of elastic gum he obtained a very little phlegm ; an oil which, though at first clear and light, became afterwards thick and coloured ; and ammoniac, the quantity of which he does not specify : There remained a coal, similar to those of other resinous substances, which weighed twelve grains. This chemist ascribes the origin of the ammoniac to the foot which colours gum elastic.

On this analysis we may observe, that it does not determine, in a very accurate manner, the nature of elastic resin : for acids act not on this substance in the same way as on fat oils ; they act on these bodies with much more rapidity than on elastic gum ; neither do caustic alkalis reduce it to a saponaceous state : nor does it melt, unless a much stronger heat be applied to it than is sufficient to reduce the most solid fixed oils to a state of fluidity : and, besides, no fixed oil ever becomes dry and elastic, like elastic resin, &c. &c. In his fifth experiment, too, the author asserts this gum to consist of two distinct substances, the nature of which he does not explain ; and concludes with representing it as a product of human industry. From these reflections, and many others which might be added, concerning these experiments of M. Berniard's, which are in other respects very well performed, we are induced to think, that much still remains to be done, as he himself acknowledges, before we can be fully acquainted with the properties of this substance, or can decide with certainty concerning its nature.

CHAP. XVI.

Of the Pure Facula of Vegetables:

THE juices of vegetables, when elaborated in their vessels, become thick, and are by degrees deposited on the surfaces of their fibres, where they contribute to their increase and nourishment, or are accumulated in a more or less solid form, in the different organs of which the vegetable consists. After speaking of the fluid parts of these organic substances, we come next to examine the substance of which the contexture of their solids is formed.—We are as yet far from being sufficiently acquainted with the nature of all those solid matters which compose the organs of plants. However, those particulars which are known to us, on this head, shew that those organs, when treated by processes which we are going to describe, are reducible to a dry, pulverulent, insipid substance, either white, grey, or variegated with different colours, insoluble in cold water, and seemingly earthy, which is called *faculum*.

To obtain this substance, the root, stem, leaves, or seed of a plant, is pounded down to a pulp with a pestle. When these parts are succulent, there is no occasion for adding water to assist the process; but this fluid is usually employed to facilitate the separation of the fibres, and to take up the attenuated pulverulent parts. When reduced by this process to pulp, the vegetable substance is then squeezed; the juice or water obtained from it by pressure is either turbid, white, or coloured; and it gradually deposits, by rest, a flaky matter, partly fibrous, and sometimes pulverulent, which is the true fæculum of the plant. Some parts of vegetables appear to consist entirely of this matter; such as the seeds of gramineous and leguminous plants, tuberculous roots, &c. These parts usually afford the finest fæculum, and the greatest quantity of that matter. As to the tender stems and leaves, their texture, being more fibrous, never affords, when treated by this process, any thing but a coarse, coloured, filamentous substance, which is known by the name of *coarse fæculum*. If, after being thoroughly dried, these be reduced to powder, and the powder lixiviated, the water takes up a much finer fæculum, precisely of the same nature with that of tuberculous roots and gramineous seeds. In the eye of the chemist, therefore, there is no other difference between these two kinds of fæcula, but that the first is produced from a part which is less fibrous, not so perfectly organized, and apparently formed of small cells, in which Nature has deposited a dry or farinaceous mucilage; whereas the second, being wrought into a tissue of fibres, needs to have its organization destroyed, and to be attenuated by art.

Strictly

Strictly speaking, all the solid parts of vegetables are capable of affording a sort of fæculum. But that which is prepared for the arts, for pharmacy, and for aliments, must here be more immediately the object of our attention. The fæcula of briony, potatoe, cassava, sago, drop, starch, are those which deserve to be particularly taken notice of, as applied to these purposes.

1. To prepare the fæcula of briony, take the fresh roots of the plant, strip off the bark, rasp the root into pieces, and then submit them to the press. The juice squeezed out by the force of the press is white, and deposits a very fine fæculum. At the end of four and twenty hours, decant off the juice; dry the fæcula. As the juice must have left in it a certain quantity of extract, it is very acrid, and purges violently. If washed before being dried, it becomes finer and whiter, but loses at the same time its purgative powers. But this way of preparing the fæcula of briony affords only a very small quantity. Much more may be obtained by diluting in water the mass which remains in the press, passing that water through a hair-sieve, and suffering it to stand undisturbed, till it deposite the fæcula which it contains. When this is deposited, let the water be decanted off, and the sediment dried. This fæculum, obtained by washing the lees, is not of a purgative nature, like the former, as the water has carried off the extractive matter in which that virtue resided. M. Baumé has observed, that the fæculum of briony, when well washed, bears an exact resemblance to starch, and that hair-powder might be made of it; by which means, the wheat made use of for that article would be spared for other purposes. The

fæcula of the roots of calves-foot and corn-flag are prepared in the same way for medical use.

3. Potatoes, being so plenteous, and affording in a crop such large increase, form one of the most useful articles of food. We can very easily extract from them a great deal of very fine white fæculum, that becomes, by roasting, boiling in water, &c. a nourishing article of food. This fæculum may be obtained by grating down the potatoes on a sieve, and pouring plenty of water upon them. The fluid carries off the finest and most attenuated portion of the fæcula, and, after standing for some time undisturbed, deposite it. Decant off the water; dry the fæculum by a gentle heat: it is now in the state of a very fine light white powder. For the preparation of large quantities of this powder, mills, or a sort of graters turning on cylinders, have been contrived, which appear to be very happily adapted to the purpose.

3. The Americans extract, from the root of a very arid plant called *manioc*, a very pleasant nourishing fæculum, to which they give the name of Cassava. In preparing it, they strip the root of its bark, grate it down, and put it into a rush-bag, of a conical figure, and a very slight loose texture, and hang the bag upon a stick, resting horizontally on two wooden forks. To the lower end of this bag they fix a very heavy vessel, which, by its weight, squeezes out the juice, and, at the same time, receives it as it runs. The juice is a very acrid and noxious poison. When the fæcula are sufficiently pressed, and all the juice drawn off, it is then dried by exposure to smoke, and passed through a sieve; and now it is in a proper state for being baked into cassava.

It is now spread on a plate of hot iron, and turned till it be so completely roasted, as to take on both sides a reddish yellow colour. In this state it is called Cassava bread. When exposed to heat in a bason, and stirred from time to time, it takes, as it dries, a granulated form; in which state it is called *couac*. From the juice that was squeezed from the fæcula, there is by degrees a very fine sweet-tasted fæculum precipitated, which is called *monsfache*, and used in pastry.

4. Sago is a dry fæculum, reduced to grains, and a little reddened by the action of fire, which we get from Java, and from the Molucca and Philippine islands.—It is extracted from a sort of palm-tree, called in the Moluccas *landan*. The trunk of that tree incloses a sweet marrow, which the inhabitants extract by splitting the tree longitudinally. They then scrape down this marrow; put it into a sort of cone or funnel made of the bark of a tree, place the cone upon an hair-sieve, and pour upon it a good deal of water.—The fluid conveys with it, through the holes of the sieve, the finest and whitest part of the marrow, leaving the fibrous part still upon the sieve.—The water impregnated with the attenuated part of the marrow is received into pots, in which the fæculum is soon deposited, and it becomes transparent.—The water is now decanted off, and the sediment passed through small plates perforated with holes, which give it the granulated form by which sago is usually distinguished.—The reddish colour of the surfaces of the grains is owing to the action of the fire by which they are dried.—These grains become soft and transparent in boiling water. With milk or broth, they make a

fort of soup, which is light, and pleasant to the taste, and is greatly recommended in phthical cases.

5. Salep, salop, salab, &c. is a substance which the inhabitants of the East prepare from a species of *orchis*. They select the finest bulbs of that plant, first peel them, and then steep them in cold, and boil them in hot water; next, after the water is well drained from them, they are strung in bunches, and dried in the air. M. Jean Moulton gives another process for the preparation of salep, by which it may be prepared from any species of *orchis*.—The roots must be rubbed, either dry or in water, with a brush, to remove the exterior pellicle, and then dried in an oven. They then become very hard and transparent. But they may be very easily reduced to a powder; and this powder, diluted in hot water, forms a nourishing jelly, the virtues of which Geoffroy mentions with very lavish praise, as highly efficacious against all diseases occasioned by an acridity of the lymph, more especially against consumptions and the bilious dysentery.

C H A P. XVII.

Of the Farina of Wheat, and of Starch.

STARCH, properly so called, is a *fæculum* precisely of the same nature with those of which we have already given an account: But as the *farina* of wheat, of which starch is a constituent part, is one of the most important matters that can engage the attention of the chemist, we shall descend to a much more particular account of this than we have given of any of the other *fæcula*.

What is called *farina*, is in general a dry, friable, insipid substance, capable of acquiring sapidity and solubility by the action of fire, and consisting of several matters, which may be very easily separated from one another. This substance is disposed by Nature in the seeds of gramineous plants, especially in those of wheat, rye, barley, oats, rice, &c. Even leguminous plants appear to contain a compound of an analagous nature. There is, however, no other substance but the *farina* of wheat, which possesses all the same properties: none

but this farina possesses that just proportion of the constituent principles to which alone all its distinguishing properties can belong. Although the farina or flour of wheat has, from time immemorial, been used as a principal article of food, yet it has only within this short time begun to be chemically examined. Messrs Beccari, an Italian physician, and Kessel Meyer in Germany, are the first chemists who attempted to separate the different matters of which farina consists. Messrs Rouelle, Spielman, Malouin, Parmentier, Poulletier de la Salle, and Macquer, have prosecuted these researches a great way farther than the above-mentioned naturalists. M. Parmentier especially has prosecuted them with very uncommon zeal and industry. His researches into the nature of these alimentary substances, the principles of farina, the different kinds of *fæcula*, and concerning nutritious vegetables in general, are undeniably the most complete and accurate of any thing that we have of the kind.

Water is of all agents the most useful, as it produces the least alteration on the various matters with which it becomes impregnated, or which it separates, according to the laws of their solubility. Accordingly, it is by this fluid that the different matters of which the farina of wheat consists are most successfully obtained separate from one another. In performing this true analysis, a paste is first to be composed of the farina with water; the paste must then be kneaded in an earthen vessel, with water pouring upon it from a cock; the fluid, as it falls upon the paste, takes up from it a very fine white powder, by means of which it acquires the colour and consistency of milk: let this process be
continued

continued till the water run off clear. The farina is now found to be naturally separated into three distinct substances—a grey elastic matter that sticks to the hand, and on account of its properties has gained the name of the glutinous, or *vegeto-animal* part,—a white powder which falls to the bottom of the water, and is the *fæculum* or starch,—and a matter which remains dissolved in the water, and seems to be a sort of mucilaginous extract. Let us proceed to an examination of the properties of each of these three substances.

§ I. *Of the Glutinous Part of Wheat.*

THE glutinous part is a tenacious, ductile, elastic matter, of a whitish grey colour. It may be extended to twenty times its natural length; and it then seems to consist of fibres or filaments, disposed beside one another in the same direction in which it has been drawn out. When the power by which it was extended ceases to act, it then returns with elastic force to its primary form. By drawing it out in different directions, it may be rendered so fine as to resemble, in the polish of its surface, the texture of the membranes of animals. In this state, it adheres with considerable force to dry bodies, and forms a very tenacious glue, which was used by some people for the purpose of re-uniting pieces of broken porcelain, long before chemists had found out the way of obtaining it in large quantities. Mr. Beccari observes, that in the best flour the proportion of the glutinous matter is from a fifth to a third part, or even more:—he remarks, too, that this proportion varies,

varies, according to the season, and the nature of the corn.

The glutinous matter has an agreeable and somewhat mucous smell; its taste is insipid; it swells amazingly when exposed to a strength of heat sufficient to dry it quickly. It dries very well by a moderate heat, or even in the dry air. It then becomes semi-transparent and hard, like a strong glue, and, like that substance, breaks with noise, and with a smooth fracture. If, when in this state, it be laid on a burning coal, or held over the flame of a taper, it exhibits all the characteristics of an animal matter; it crackles, swells, becomes liquid, is agitated, and burns in the same way as a feather, or a piece of horn, exhaling a strong foetid smell. When distilled in a retort, it affords, like animal matters, water impregnated with ammoniac, ammoniacal carbonate, and an empyreumatic oil: the carbonaceous residue is very difficult to incinerate, and is found to contain no fixed alkali.

The gluten, when exposed fresh to a moist and hot air, is altered, and actually putrefied in the same manner as animal matters. If it still retain a little starch, then the starch, passing into the state of acid fermentation, retards and modifies the putrid fermentation of the gluten, and reduces it to a state in which it is much like cheese. In this way Rouelle the younger prepared, from this gluten, a species of cheese, in taste and smell much the same with Dutch cheese, and that of Gruyere.

Water does not at all dissolve this glutinous matter. When boiled in that fluid, it becomes solid, and loses its tenacity and elasticity, but neither acquires a taste, nor becomes soluble in the saliva. We may, however,
observe,

observe, that to the water which was used in making the paste the gluten owes its elasticity and solidity. In the farina, this vegeto-animal matter, which is thus susceptible of a solid elastic form, was in an incoherent and pulverulent state; but when the water is poured upon the farina, and mixed with it, those particles which are of a glutinous nature absorb the fluid, and are by its means so closely united, as to form, in a short time, that sort of elastic solid which is known by the name of Gluten. Water, therefore, contributes greatly to the formation of this substance, which is perhaps to be considered as a peculiar compound saturated with water, and, for that reason, not capable of absorbing any more. So true is this, that if it be deprived of its water by desiccation, it loses entirely its elastic and adhesive powers.

Most saline substances act either with more or less force on this gluten. Potash and soda, in a caustic and liquid state, dissolve it with the help of a boiling heat. The solution is turbid, and, on the addition of acids, deposits gluten, which, however, is destitute of elasticity.

The mineral acids dissolve this gluten. The nitric acid dissolves it with great activity; and M. Berthollet has observed, that this gluten, as well as animal substances, gives out azote gas, when exposed to the action of the nitric acid. After the emission of this elastic fluid, the solution affords a great deal of nitrous gas, and takes a yellow colour. By evaporation, it affords oxalic acid in crystals. The sulphuric and the muriatic acids form, with this substance, brown or violet solutions. A sort of oily matter is separated from these solutions:

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the gluten exists in them, in a real state of decomposition. M. Poulletier, who has made many experiments on this matter, has discovered, that from these combinations, dissolved in water or alcohol, and evaporated in the open air, there may be ammoniacal salts obtained.

From what we have related concerning this substance, it appears, that it is entirely different from all those which we have before taken notice of, as existing in vegetables; and that in many of its distinguishing properties, it bears a great resemblance to the fibrous part of blood. It is to this gluten the farina of wheat owes its property of forming a tough paste with water, and its readiness to rise with leaven. It appears either not to exist, or to exist only in a very small proportion, in the farina of other vegetable substances, such as rye, barley, buckwheat, rice, &c. all of which form solid, opaque pastes, scarcely ductile, and brittle, and which can scarce be raised when exposed to the same temperature by which paste of the farina of wheat is raised. No other substance but flour of wheat, therefore, is possessed of all the qualities necessary for making good bread.

M. Berthollet is of opinion, that this glutinous substance, like animal matters, contains phosphoric salts, which are the occasion of its coal being so difficult to incinerate. Rouelle the younger has discovered a glutinous substance, resembling that of the farina of wheat, in the green fæcula of plants, which afford, by analysis, ammoniacal carbonate and empyreumatic oil, like the vegeto-animal matter of which we have been speaking

§ II. *Of the Starch of Wheat.*

STARCH, the amylaceous fæculum, is the most copious part of the farina. This is the substance which is carried off, and afterwards precipitated from the water with which the paste is washed, in order to obtain the pure gluten. This substance is very fine, feels soft, and has no perceptible taste. Its colour, when it is extracted by the process above described, is a dirty grey-white; but the manufacturers of starch render it exceedingly white, by steeping it in an acid water, which they call *sour water*. It appears, from the experiments of M. Poulletier, that the fermentation which takes place in that fluid whitens and purifies the starch, by attenuating, and even destroying, the extractive mucous substance which is precipitated with it in the first washing. Starch, chemically considered, is a mucilage of a peculiar nature. This mucilage, which by some chemists has been mistaken for an earth, is very different from the gluten. It does not, like the gluten, diffuse an empyreumatic smell when it burns. When distilled by naked fire, it affords an acid phlegm, of a brown colour, and, towards the conclusion of the process, a very thick empyreumatic oil. The coaly residue is easily enough incinerated; and its ashes are found to contain fixed alkali.

Starch is not soluble in cold water; but when boiled in water, it forms with the fluid a glue, or rather what in French is demoninated by the peculiar name of *empois*. This compound, when exposed to damp air, loses

by degrees its consistency, ferments, becomes sour, and is covered over with mouldiness.

The nitric acid affords, with this *feculum*, oxalic acid, perfectly the same with that of which we have spoken in the foregoing chapter.

As starch forms the greatest part of flour, there can be no doubt of its being the principal alimentary substance contained both in flour and in bread.

§ III. *Of the Extractive Mucilaginous Part of the Farina.*

BY evaporating the clear water that had been used in washing the paste, and had deposited the starch, M. Poulletier obtained a viscous, adhesive matter, of a brown-yellow colour, the taste of which was faintly saccharine. This substance, to which he gave the name of *muco-faccharine*, displayed, in combustion and distillation, all the same phenomena with sugar. By it the acid fermentation is produced in the water which swims over starch; for, as Macquer has observed, starch is not at all soluble in cold water. The *muco-faccharine* matter exists in the *farina* of wheat only in a very small proportion. It may possibly be more copious in the *farina* of some other vegetable substances.

However small the proportion of this substance in the *farina* of wheat, yet there can be no doubt of its acting a peculiar part in the fermentation which takes place in paste, and causes it to rise. The nature of this motion, so necessary to render bread wholesome, is still but very little known. It would appear to be nothing more but
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the beginning of a putrid fermentation in the gluten, an acid fermentation in the starch, and perhaps a spiritous fermentation in the mucoso-saccharine matter. These three incipient fermentations, which mutually oppose each other, are perhaps what produces the compound, so much lighter than dough, which, by baking, and a proper exposure to heat, forms bread. One thing certain is, that in bread all the three substances which we have here examined, are found existing together, but so much altered, that they can no longer be extracted separately. Even the action of heat alone, without the motion of fermentation, is sufficient to change the nature of these three substances, and combine them in such a manner, that even from bread, unleavened, or baked without being raised, Malouin and M. Poulletier tells us, the gluten can no longer be obtained.

From these particulars, we understand how that all flour but that of wheat, and still more the leguminous or farinaceous seeds, such as beans, pease, chesnuts, &c. are far from possessing the qualities requisite for making good bread.

C H A P.

C H A P. XVIII.

Of Vegetable Colouring Matters, and their Application to the Art of Dyeing.

VEGETABLES contain colouring matters through all their organs. These matters are extremely various. It often happens, that a vegetable matter, which has of itself no apparent colour, assumes a very distinct one when exposed to the action of certain menstrua. The art of dyeing, all the processes of which are entirely chemical, is founded on the knowledge of the solubility of these colouring parts of vegetables, in various menstrua,—of the way of applying them, so as to communicate colour to other substances,—and of rendering them permanent and tenacious on those substances. In examining the properties of each of the colouring matters, we will have occasion to give some account of the principles of this important art, on which Messrs Hellôt, Macquer, le Pilcur d'Apligny, Hecquer

Macquet d'Orval, and the Abbé Mazéas, have already published excellent works.

It appears that the colouring matter of vegetables, properly so called, is still unknown. Rouelle was of opinion, that the green part, so copious in the vegetable kingdom, was similar in nature to the gluten of the farina. But it is certain, that this matter exhibits different chemical characteristics, according to the diversity of the bases with which it is united. It is therefore rather the base than the colouring part itself of which we speak, when we say, such a colour is extractive, and such another colour resinous, &c. The substance which really colours those parts of vegetables that are employed in the arts is no doubt a very subtle body, perhaps not less so than the principle of smells. There is even some reason to think, that it consists solely in a certain modification of the solid and liquid parts of vegetables.

It may be proper to recollect here, that the colouring of vegetables depends, in a great measure, on the contact of light. But in what manner the contact of light contributes to the production of colours, is a problem of which the researches of the natural philosopher have as yet afforded no solution. However that may be, as it is impossible to separate the colouring matter entirely from the vegetable base to which it is united, it is generally agreed to consider these two substances together as the colouring matter of plants.

Of all chemists, Macquer has best distinguished the nature of the different colouring matters of vegetables, considered with respect to the art of dyeing: And his theory concerning the application and the fixation

of colours on other substances in dyeing, is beyond a doubt the most satisfactory. As I intend here to connect this theory of dyeing with the history of the chemical properties of the colouring parts of vegetables, I shall begin with the consideration of those properties.

1. A great many vegetable colouring matters, which are either extractive or saponaceous, dissolve very readily in water. Bastard rocket, madder, logwood, redwood, and Brasil wood, afford yellow or red colours of this sort. It is easy to see, that matters dyed with these colours must lose their dye in water: on this account, there is employed, to render these colours permanent, some additional matter capable of fixing and decomposing them; such as crude tartar, alum, and other salts. These salts are called *mordants*. A solitary acid might produce the same effect; but would alter the colouring matter. The superfluous portion of the acid of the alum combines with the alkali of the saponaceous colouring extract, and occasions the precipitation of the resinous part of that extract, which is then insoluble in water, upon the substance intended to be dyed. This colouring part, however, which is rendered insoluble by the alum, or the mordant, is of two kinds. The first is very solid, and resists the action of air, of soaps, and of all the liquors used by dyers as proofs. The other is liable to be altered by air, and still more by the proof-liquors: it is called a false dye. In order to ascertain the nature of these colours, and the durability of dyes in general, M. Berthollet has proposed the use of the oxygenated muriatic acid. This acid effects, in a very short time, by means of its excess of oxygen, what the vital air of

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the atmosphere takes a long course of time to accomplish : And, by observing what quantity of this acid is necessary to discolour and entirely whiten any died stuff, as well as the time which it takes to produce the effect, a judgment may be formed of the solidity and the durability of the colours thus submitted to examination.

It is to be observed, that wool takes a dye better than any other substance ; and next after wool, silk, cotton, and flax, in the order in which they are here mentioned, receive a dye, each of them with more difficulty than the preceding one, and lose it sooner.

Those authors who have written upon the art of dyeing have maintained different opinions concerning the way in which colouring matters act on the substances exposed to their operation. Many have supposed, that in proportion as the pores of the substance to be dyed are more or fewer, greater or smaller, the colouring matter is more or less completely applied to it ; and that the reason why wool takes a colour better than silk or thread is, because its pores are more open and more numerous than those of either of these substances. But Macquer thinks the true cause which renders the application to any substance more or less easy, is the relation between the colouring matter and the body to be died, being nearer or more remote. Dyeing, in his opinion, is actually nothing but painting, which succeeds and lasts only by virtue of an intimate affinity between the colouring matter and the dyed substance. That celebrated chemist adopted this opinion in consequence of the numerous experiments which he made in the art of dyeing ; which is indeed highly indebted to his discoveries.

2. There is another class of colouring matters, which seem to consist of resin and saponaceous extract. Macquer calls them *resino-terreous* matters. When these matters are boiled in water, the resinous substance which they contain is melted, and diffused through the fluid, by means of the action of the heat, and the solution of the saponaceous part : but it is precipitated as the bath or decoction cools. When, therefore, wool, or any other matter, is immersed in a decoction of mixed colouring matter of this kind, the resin is separated by cooling ; and, without requiring any farther process, fixes on the substance thus exposed to it. Not being soluble in water, it forms a permanent dye. Colouring matters of this kind are obtained from almost all astringent vegetables, such as the husks of nuts, the roots of the walnut-tree, or of dock, sumach, bark of alder, sandal wood, &c. These colours are all yellow, and are called by the dyers root-colours. They are generally used to form a good ground, on which colours of a higher lustre may be laid. We may further remark, that the colouring matters, for the application of which no particular preparation, either of themselves, or of the bodies to which they are applied, is requisite, afford the simplest tincture, and are the easiest applied to use.

3. The colouring principle of various other substances exists in a matter that is purely resinous, and insoluble in water. Several of these matters are not soluble even in alcohol ; but in alkalis they are all dissolved, and reduced into a sort of saponaceous state, in which they are soluble in water.—The following are the principal colours of this sort used in dyeing.

A. The annatto, a kind of *fæculum* obtained by maceration from the seeds of the *urucu* putrefied in water. This *fæculum* is deposited during the putrefaction of the substances. It is at first red, but in course of time becomes of a brick-dust colour. Stuffs intended to be dyed with this matter are immersed into a lixivium of this paste, with the *cendres gravelees*, which we are shortly to describe, mixed together in water. Without the assistance of any mordant, there is deposited on the substances immersed into this lixivium a golden yellow, or orange colour, of considerable beauty.

B. The flower of *carthamus*, or bastard saffron, affords, by the same process, a very beautiful red colour. This flower has two different colouring parts; the one purely extractive, and soluble in water; the other resinous.—To obtain the latter, the soluble part of the *carthamus* must first be carefully washed away: What remains after the washing must be mixed with the *cendres gravelees*, or soda; this mixture is then to be formed into a lixivium, and employed in dyeing. But as the alkali alters the colouring matter, and tarnishes the colour, the dyed substance is steeped in water, acidified by lemon-juice. This acid seizing the alkali, the colouring matter is left at liberty, in consequence of which it regains its original properties, and becomes red. By a similar process, there is a coloured *fæculum* obtained from *carthamus*, which, mixed with briancon-chalk in powder, composes the *rouge* made use of by the ladies.

C. Archil is a paste prepared from moss and lichen, macerated in urine, with lime. The lime disengages the volatile alkali; and this causes the red colour to appear. Archil diluted in water communicates a dye without any

other preparation. It gives a violet colour ; but this is a false dye, which is altered in the air, and rendered yellow by the action of acids

D. Indigo, the colour of which is a deep violet blue, seemingly of a cupreous nature, is a *feculum* prepared at St Domingo, and in all the Antilles, &c. by macerating the stalk of the *antillo*, or indigo plant, in stone troughs, with water. The water becomes blue ; and, after it has been for some time violently stirred, the *feculum* is precipitated. The indigo separated from the water is put into cloths to drain. It is then dried in small wooden boxes, and when dry broken into pieces. When it floats on water, and burns entirely away on a red-hot shovel, it is esteemed good. The colouring part of it is extracted by alkalis, and applied to the matters intended to be dyed, without any farther preparation. It cannot be brightened by acids, as these would alter the colour.

4. There are certain colouring matters soluble in oils. Alkanet, or the red root of a sort of bugloss, communicates its colour to oil. Alcohol likewise dissolves several colouring matters : Green *fecula* dissolve in it as well as in oil. It may be easily understood, that these colours cannot be used in dyeing, because the liquids necessary to extract them cannot be employed.

Such are the principal facts at present known concerning the nature of vegetable colours. From these it appears, that any of the immediate principles of vegetables may become the base of their colouring parts ; as we find them to be saponaceous, resinous, and extractive. Some of them even appear to be of the same nature with fixed oils, and are not soluble either in water or in alcohol, but dissolve readily enough in alkali. Lastly,
There

There are, according to Rouelle, some of these colouring parts of the same nature with the glutinous part of vegetables.

All vegetable colouring matters possess a more or less powerful attraction for oxygen. There are few of them that do not experience a more or less sudden alteration from this principle. The oxygenated muriatic acid alters almost the whole of them, and converts them into white or yellow. Most part of vegetable colours contain different proportions of oxygen, and frequently owe their shades to a difference in the quantity of this principle. This is the reason why all these colours are prepared with the contact of air, because this contact has a singular effect upon their dyes. See M. Hausman's Memoir upon indigo (*Journal de Physique*, 1788), and my Memoir on the colouring of vegetables by oxygen. *Annals of Chemistry*, Vol. IV.

C H A P. XIX.

Of the Analysis of Plants by Naked Fire.

AFTER examining all the matters which can be obtained from vegetables, by such simple means as produce no alteration in their nature, and considering these matters as the immediate principles of those organized bodies, it will next be proper to consider what alterations they are liable to suffer from fire.

The ancient chemists were acquainted with no other method of analysing vegetables but this; and all their inquiries into the nature of these substances were directed only to discover, how much spirit, oil, and volatile salt, they afforded by distillation in the retort. At present we give but little credit to the results of this process.—We know, that all plants give nearly the same products; and the distillation of a great many different vegetables, by chemists in other respects very skilful and highly respectable, has only served to undeceive us with respect to this analysis. How, indeed, can it be thought, that the action of fire, which is exerted on all the different

ferent principles contained in a vegetable, extract, mucilage, oil, resin, saline matter, gluten, &c. and which decomposes each of them in a peculiar manner, can afford any certain information concerning the nature and the quantity of those principles? especially when we observe, that the products of these different decompositions form, by mutual combination, new bodies, which did not exist before in the vegetable under examination. The analysis of vegetables in the retort is therefore false and complicated.

However, as, in a chemical examination of any substance, we should not refuse the use of any means which art supplies for the discovery of its nature, we may have recourse to this analysis, and observe its effects, provided we be sufficiently on our guard against giving too much credit to its results: Nay, it sometimes happens, that when, in a series of experiments on any vegetable substance, in order to discover its chemical properties, we compare the effects of aqueous, spiritous, and oily menstrua on that substance, with the alterations which it suffers from fire, these alterations accord with the action of the solvents, and shew, by the products of the distillation, what matter is contained in a larger or a smaller quantity in the vegetable, the nature of its salt, &c. But, that we may be able to make such important deductions from an analysis by naked fire, it is requisite, 1. That we be well acquainted with the manner in which fire acts on each of the immediate or proximate principles of vegetables, the extract, the mucilage, the saline matter, the oily juices, fluid or dry, &c. 2. That we compare the products of the distillation of the whole vegetable with those which its proximate principles generally

ly

ly afford when treated in the same manner. 3. That we, at the same time, analyse the vegetable by menstrua, in order that we may distinguish its proximate principles, and draw some useful inferences concerning the alterations which it suffers from fire.

The process necessary for the distillation of vegetables by naked fire, is very easy and very simple.—Put into a glass or earthen retort a certain quantity of the dry vegetable :—care must be taken, however, to fill the vessel only half, or not more than two thirds full. Place the retort in a reverberatory furnace ; to its neck adapt a balloon of a proper size. There used to be formerly recommended for this purpose, a balloon perforated with a small hole, to afford a passage for the air which was said to be disengaged, in a smaller or a larger quantity, from the vegetables, and was likely, if confined, to break the vessels. At present we know, that the aeriform fluid which escapes from these bodies, when subjected to distillation, is never air, but rather carbonic acid and hydrogenous gas, with carbonaceous matter dissolved in them. But as these elastic fluids are products of the vegetable, decomposed by the action of fire, as well as the phlegm, the oils, and the volatile salts, it is no less necessary to collect them than these latter substances. For this purpose, there may be employed a perforated receiver, joined to a curved syphon, entering by one end into a bell-glass filled with water, or rather with mercury. By this means, the liquid products are collected into the receiver, and the aeriform products into glass vessels, placed on the shelf of a pneumatocchemical apparatus. When the substance distilled is such

as can afford any concrete salt, there is put between the retort and the receiver an adapter, or long glass vessel, in the form of a spindle, on the sides of which the salt fixes as it is sublimated. In this sort of distillation, the fire should be gradually and cautiously applied, that the products may be obtained in the order of their volatility, without being confounded together. The process begins with placing a few coals under the retort, and the fire is by degrees increased till the vessel become red-hot, and the passing of the products into the receiver appear to have ceased. The retort is now suffered to cool, the luting removed from the apparatus, and the products examined.

Although the products obtained by the distillation of vegetables are never to be entirely depended upon, yet so much do they differ from one another, that they well deserve to be carefully distinguished.

The first product obtained is an aqueous liquor, impregnated with some odorous and saline principles. This phlegm assumes by degrees more colour, and more saline properties. After it, comes a coloured oil, the colour of which becomes deeper, as the process advances. This oil is sometimes light and fluid, at other times weighty, and liable to become solid. It constantly exhales a strong empyreumatic smell. At the same time with it, there is a smaller or a greater quantity of elastic fluids disengaged; which are either carbonic acid, or hydrogenous gas, or, which is most frequently the case, a mixture of these two substances. At the same instant, too, ammoniacal carbonate is sublimated, if the nature of the vegetable be such as to afford it. After all these matters
have

have passed, the vegetable is found reduced to a carbonaceous state. Let us now return to a more particular examination of each of these products, and attempt to distinguish what is their nature, and to what substances they owe their formation.

The phlegm, according to the ancient chemists, is owing to the water which enters into the composition of the vegetable, and in part to the water of its vegetation; and this especially, when the body analysed is not entirely dry : and accordingly the quantity of this phlegm is greater or less in proportion as the vegetable has been more or less thoroughly dried before it was submitted to distillation. Several modern chemists are of opinion, that the water obtained from the distillation of vegetables is formed by the union of hydrogen with the oxygen contained in these organized substances. This phlegm is coloured of a lighter or a deeper red by the small portion of oily matter which it carries off with it, and which is reduced to a saponaceous state by the salt that is usually dissolved in it. The saline matter in union with it is most commonly acid ; on which account this phlegm usually reddens syrup of violets, and produces an effervescence with alkaline carbonates. This acid belongs to the mucilages and oils. The phlegm is sometimes of an alkaline nature, as in the distillation of nitrous and cruciform plants, and of emulsive and farinaceous seeds. It is frequently ammoniacal ; because the ammoniac which follows immediately after the acid combines with it. Of this fact full evidence may be obtained, by throwing a little fixed alkali or quicklime

lime into the phlegm : When it is ammoniacal, there is a lively smell of ammoniac disengaged from it.

The oils obtained from vegetables by distillation in a retort are all strong-smelling and high-coloured, and exhibit all of them nearly the same properties. Those parts of vegetables which contain a great quantity of these inflammable fluids, such as emulsive seeds, afford, when analysed, a good deal of oil. The odorous plants afford an oil, which, in the beginning of the process of distillation, retains somewhat of their smell, but soon assumes the common characteristics of all these oils ; that is to say, the colour, gravity, and empyreumatic smell, by which they are distinguished. All of these fluids are highly inflammable ; the nitrous acid causes them to flame : they are soluble in alcohol, and bear, all of them, some resemblance to the vegetable from which they were obtained. By rectification, they may all be rendered very fluid, very light, colourless, soluble in alcohol ; in a word, they may thus be reduced to the state of æthereal or volatile oils.

These empyreumatic oils are formed by the action of the fire, and had no previous existence in the vegetable.

With respect to the volatile salt, which is nothing but ammoniacal carbonate, it is obtained only from a few vegetables ; but we must not imagine, as has been advanced by some chemists, that it is to be obtained only from cruciform plants. All plants, in general, containing a certain quantity of glutinous or vegeto-animal matter, afford more or less ammoniac ; because, as has been fully proved by M. Berthollet, that principle of

vegetables always contains azote. It very seldom happens, however, that any quantity of it can be obtained in a concrete state: it is often dissolved in the last portions of the phlegm. This salt is produced by the union of the azote with the hydrogen of the oil; on which account, it does not usually pass till the end of the distillation. It even appears, that what is carried up by the phlegm in the analysis of some plants, such as the cruciferous plants, poppy, rue, &c. is always the product of some new combination; for Rouelle the younger has shewn, that the plants themselves do not contain it in their natural state.

The elastic fluids which are disengaged during the distillation of vegetables, are to be included among the products that may be obtained from them. Their nature appears to depend on the nature of the vegetable. A plant which contains a good deal of oily combustible fluids, affords hydrogenous gas. Mucilages, on the contrary, afford carbonic acid. We have mentioned, under the article Oxalic Acid, that Messrs Bergman and Fontana have obtained from them a large quantity of carbonic acid, and that Fontana thinks vegetable acid to be composed chiefly of it. It is therefore not at all surprising, that mucilages, in which Bergman found the same radical acid as in sugar, should afford carbonic gas when analysed. Lastly, There are some vegetable matters which afford azotic gas. These aeriform fluids pass only towards the end of the process of distillation; because they are not disengaged till the instant when the vegetable is totally decomposed. Hales, who was not acquainted with their nature, observed, that the

more solid the vegetable, so much the greater was the quantity of the air disengaged from it during its distillation : and he of consequence considered that element as the cement which produced the solidity of vegetable bodies. From what we have had occasion to shew, the reader may easily judge of the truth of this hypothesis.

C H A P.

C H A P. XX.

Of Vegetable Coal, or Charcoal.

CHARCOAL is the black residue of vegetable matters, whose volatile principles have been entirely decomposed in close vessels. None but organic matters, containing the combustible substance known by the name of oil, afford charcoal. The production of the substance which we are beginning to consider, used to be ascribed to the decomposition of this latter substance; but it is now beginning to be understood as a fact, that the carbonaceous matter exists ready formed in the vegetable; and that which is accomplished by the operation of fire, is the separation of the volatile principles that existed in union with it.

Charcoal is generally black, brittle, sonorous, and light. If the vegetable of which it has been formed was very compact, and contained but a small proportion of fluid substance, it still retains a vegetable form. But again, when the plant decomposed is tender, and contains

a good deal of juice, the fluids, as they are disengaged, destroy the organic texture of the vegetable, and leave a friable coal, which exhibits not the form of a decomposed vegetable. Different vegetable matters afford coal in greater or less abundance, according to the solidity, and the form of their texture. Wood affords much more of this substance than herbs; gums afford more than resins; and resins more than fluid oils. Every different vegetable matter appears to contain this substance in a particular proportion,—if we consider charcoal as one of the immediate principles of vegetables.

Charcoal is a body possessed of singular properties, which are in general but very little known.—Though it be of the highest importance in chemistry, and exhibit phenomena entirely of a singular nature, yet no chemist has as yet engaged in a series of experiments with a view to ascertain its nature. Stahl, who paid more attention to it than it has since obtained from any other person, thought it the principal repository of phlogiston. We know scarce any thing concerning the properties of charcoal, but what relates to the economical purposes to which it is applied: the labours of the learned afford no full information concerning it.

The physical properties of charcoal are different, according to the nature and the state of the vegetables from which it is formed. It is sometimes hard, and retains in some degree the organization of the vegetable; at other times it is friable, and somewhat pulverulent. Pure oils afford a coal in very fine, and seemingly levigated molecules, called lamp-black. Its gravity varies in like manner. When well made, it has no perceptible

taste or smell. Its colour is subject to as many varieties as its other physical properties; it is either of a lighter or a deeper, a sparkling or a dull colour. But the chemical properties of this product of fire, deserve the most particular examination.

Charcoal exposed in close vessels to the utmost violence of fire, suffers no alteration. When heated in a pneumato-chemical machine, it affords no hydrogenous gas, unless it happen to contain moisture: an intense heat reduces it to vapours. When heated in contact with air, it burns it to ashes; but with singular phenomena, which are to be carefully distinguished from those of other combustible matters. As soon as it takes fire, it becomes red, and exhibits a white flame, which is more considerable in proportion as the mass of charcoal is larger. No sort of smoke exhales from it; but it is reduced into carbonic acid, an elastic fluid, which, from the fine experiments of M. Lavoisier, appears to be nothing but a combination of the carbonaceous principle with the oxygenous—of the latter of which principles three fourths of it consist. It is on this account that charcoal consumes slowly, and leaves nothing but a cinder, more or less white, partly of a saline, and partly of an earthy nature. Different sorts of charcoal are of different degrees of inflammability; and this distinction is the most useful to the arts of all the facts respecting charcoal. Some sorts of it burn readily with flame, and are quickly consumed; others are difficult to kindle, burn but slowly, and remain a long time red-hot, before being reduced to ashes. Some of them,—for instance those of oils,—burn indeed, but with the utmost difficulty. This property they seem to owe to the ob-

sinate

imate adhesion of the carbonaceous principle to the fixed salts of the vegetables ; and as the proportion of these last varies in each vegetable, the density of the charcoal, and the quantity of residue which it leaves after combustion, depend on this cause.

Charcoal, when exposed to the air, attracts moisture ; probably because it is very porous ; and perhaps, too, on account of its containing salts, though these salts be not in a disengaged state. When moistened, it affords hydrogenous gas, which is produced by the decomposition of the water : for, when this fluid is passed through an earthen tube, filled with red-hot charcoal, the two bodies are converted into hydrogenous gas and aeriform carbonic acid. Nothing now remains but a little ashes. Rouelle has taken notice, that fixed alkali dissolves a pretty considerable quantity of charcoal by fusion.

The sulphuric acid, when exposed to a strong heat with powder of charcoal, is decomposed by this combustible body, which has a stronger affinity with oxygen than sulphur has.

The nitric acid is decomposed with much more rapidity by charcoal. Dr Priestley observed, that there was a good deal of nitrous gas produced from this mixture. Macquer saw the nitric acid, with the help of a certain degree of heat, produce a very discernible effervescence with this body. M. Proust has succeeded in kindling charcoal with acid of nitre, the weight of which was one ounce four drams and twenty-three grains, in a bottle containing an ounce of distilled water. The result of his experiments is of no small importance : And I shall therefore here insert an account of them in his own words, taken from his *Observations on Pyrophori*

without alum, &c. inserted in the *Journal de Medicine*, for July 1778.

“ A coal of the extract of carthamus, reduced to powder, and newly calcined, detonized in a very lively manner with the nitrous acid; and the combustion was so rapid, as to raise the powder in the form of a very beautiful sky-rocket. I calcined, likewise, very fine powder of common charcoal; and the detonation succeeded very well.

“ Into a glass retort, perfectly dry, I introduced about a dram of powder of charcoal; after which I poured into the same retort about as much nitrous acid: the nitrous acid no sooner reached the bottom of the retort, than a detonation was produced with the utmost rapidity. There proceeded out of the mouth of the retort, as I held it in my hand, a stream of flame, more than four inches in length, carrying with it some of the powder, and very dark-coloured vapour of the nitrous acid: The vapours were condensed into a green and somewhat fuming liquor, which proved to be nitrous acid, weakened by the water which entered into the composition of that which detonized first. I poured a new quantity of nitrous acid on the coal which still remained in the retort, and continued to inflame it in the same way, till the whole quantity was exhausted.

“ This experiment I repeated with calcined lamp-black; the same phenomena were exhibited. In the retort there remained only a very small portion of ashes, sometimes half vitrified, and sticking to the bottom of the retort.

“ All

“ All charcoal is usually impregnated with a considerable quantity of moisture. I found that charcoal calcined in the evening was next day unfit for this detonation, having acquired, during the intervening space, a sensible quantity of moisture. But, what is very singular, these experiments are so capricious, that they do not always succeed, even with the same charcoal, and the same acid, intermixed in the very same proportions. By the following expedient, I believe, success may be secured : When the acid is poured on the middle of the charcoal, it does not take fire at all ; but, again, when the acid is made to trickle down the sides of the crucible or capsule, till it reach the bottom, then detonation infallibly follows, and the powder is raised and kindled by the nitrous acid. When the nitrous acid is all consumed, the detonation ceases of course, and the rest of the charcoal remains black.”

We know nothing concerning the action of the other acids on charcoal.

This body, with the help of heat, decomposes all sulphuric salts, forming in consequence sulphures with various bases.

Charcoal causes nitre to detonize ; the nitre burns it by means of the vital air which this saline substance affords by the action of fire. There is a preparation made for the purposes of chemistry and pharmacy, which is called *nitre fixed by charcoal*. Mix two parts of nitre with one of powder of charcoal ; put the mixture into a red-hot crucible : A lively detonation immediately takes place : And, when this detonation ceases, there

remains a white mass, which attracts moisture from the atmosphere, and is nothing else but the fixed alkali of the nitre and the charcoal combined with carbonic acid. On lixiviating this matter, the water dissolves the fixed alkali; and what remains is a substance thought to be of an earthy nature.

Sulphure of potash dissolves charcoal with great facility, both by the dry and by the humid way: it even combines with it more readily than any other substance. We owe this discovery to Rouelle.

Metals do not combine with charcoal; but metallic oxides are reduced, when exposed in contact with this body, to heat more or less intense. We have already seen, under the article of Metals, that this phenomenon is owing to the strong affinity between oxigene and pure carbonaceous matter.

The action of vegetable substances on charcoal has been but little examined. We know only, that charcoal mixed with fat oils, renders them susceptible of inflammation by the nitrous acid; a fact which confirms Rouelle's beautiful theory concerning the inflammation of oils by that acid.

Within these few years, charcoal has been alledged to be very proper for whitening and purifying vegetable liquors, when heated along with them.

All that has been here said concerning the known properties of charcoal, tends to prove that this body is a compound of a combustible matter, saline substances, and earths.

The peculiar combustible matter which constitutes
: than three fourths of the composition of charcoal,

or

or pure carbonaceous matter, is but little known. It appears only to be one of those bodies which have the greatest affinity with oxigene; so great indeed, that it is capable of separating it from every other substance; and that, in certain circumstances, it exhibits properties much the same with those of native *carbure* of iron.

The uses of charcoal in the arts are sufficiently known; it is likewise of great use in chemical operations.

CHAP. XXL

Of the Fixed Salts and Earths of Vegetables:

WHEN a vegetable coal is burnt, there remains a grey, blackish, or white matter, according to the nature of the coal. This substance, which is called *ashes*, is of a very compound nature. When the charcoal is thoroughly burnt, it contains only different saline and earthy substances, mixed with a little iron and a little manganese. When, again, the charcoal does not burn very freely, the ashes produced from it sometimes contain a little inflammable matter which has not been consumed. M. Lavoisier, on examining the ashes of the wood made use of by the manufacturers of saltpetre, found it to contain extractive and resin-extractive matters. The saline substances obtained by lixiviation from the ashes of charcoal, have received the name of the Fixed Salts of Plants. There are three sorts of salts obtained by the incineration of vegetables, the nature of which we shall here describe.

1. Potash, which is prepared in the north by burning wood, which they there possess in great plenty. This salt is very impure; it often contains combustible matters by which its whiteness is impaired, a variety of neutral salts, such as sulphate of potash soda and lime, muriate of potash and of soda, a little carbonate of soda, oxide of iron, and earthy matters. To purify this salt, and extract from it pure potash, it is dissolved in the smallest possible quantity of cold water. The fluid takes up the alkali, with some neutral salts; and the earth, charcoal, iron, and sulphate of lime which the potash frequently contains, are separated by filtration. The solution is evaporated to a pellicle, and then suffered to settle and cool, in order that the different neutral salts which it contains may be formed into crystals. When, at length, after repeated filtration, evaporation, and crystallization, the lixivium ceases to afford neutral salts, it is evaporated to dryness, and calcined. The salt thus obtained is carbonate of potash, intermixed with caustic potash. It always contains, however, some neutral salts, and a small portion of earthy matters, which may be separated by forming these salts and earthy matters into a strong solution with water, suffering that solution to settle and rest for some time, and then separating, by filtration, the sediment thus formed. The potash may now be used with confidence as pure, even in the nicest chemical experiments.

2. Soda is the residue remaining after the combustion of certain plants which grow on the sea-shore. It is prepared at Alicant, in Languedoc, at Cherbourg, &c. by the combustion of various plants. At Alicant, the kali is employed; at Cherbourg, the alga and fucus, commonly known by the name of *varsch*. The

former of these plants contains a good deal more soda than the other ; which indeed affords but very little. These plants are made very dry, and burnt over a trench. At Cherbourg, when the combustion is considerably advanced, and the ashes are become very hot, they are violently stirred and kneaded together with large poles. By this motion, the substance, being hot enough to suffer a sort of semi-vitrification, is formed into solid, hard pieces, which are sold in commerce under the names of *stone-soda*, *salicore*, *salicote*, *la marie*, and *alun catin*. The names by which it is chiefly distinguished, and which denote its particular state, are those either of the country from which it comes, or the plant from which it is obtained. The soda of Alicant, called also *barilla*, is the best for the purposes of chemistry, and of all those arts in which fixed alkali is necessary.

The soda of Cherbourg, or *varech*, contains less alkali, and should not be used in chemistry ; but in glass-works it is very advantageously employed ; for it contains vitreous frit, which answers the purposes of the glass-maker, by promoting the vitrification of the other matters.

Common soda, chemically considered, is a compound of caustic soda, carbonate of soda, a small proportion of carbonate of potash, sulphate of potash and soda, muriate of soda, charcoal, iron in the state of *Prussian blue*, as has been observed by Henckel, and earth partly free, partly combined with fixed alkali, as in that of Cherbourg. To separate these substances, and obtain the carbonate of soda in a pure state, they are formed into a lixivium with cold distilled water : this lixivium is filtrated, in order to separate the earth, the iron, and the carbonaceous

carbonaceous matters : lastly, it is evaporated in the same way as potash. This alkali is more easily purified than potash ; for as it crystallizes sooner, it separates more readily from the caustic soda. It however carries with it, when it crystallizes, some of the neutral salts and the Prussian blue contained in the lixivium, which can be separated only by repeated solution, and successive crystallization.

3. There are fixed salts prepared in pharmacy, which have been strongly recommended by Takenius, and still bear his name. This chemist's process consists in putting the plant from which the salt is meant to be extracted into an iron pot, and heating that vessel till its bottom become red-hot : the plant is constantly stirred, and exhales a good deal of smoke : at length it kindles : it must now be covered up with a lid, which may suffer the smoke to escape, but extinguish the flame. By this means, the plant is gradually consumed. When reduced to a sort of blackish cinder, it is lixiviated with boiling water ; and, on evaporating this lixivium to dryness, a yellowish or brown salt is obtained. This salt is often alkaline, but very impure ; it contains a good deal of extractive matter, from which it derives a colour, and which is mixed with all the neutral salts contained in the plant : it is in a sort of saponaceous state, which makes it very fit for being employed in medicine. But we must not imagine that it possesses all the virtues of the plant from which it was extracted ; for the combustion necessarily alters the principles of the plant. It would be worth while to examine, by a chemical analysis, the several fixed salts prepared in Takenius's way, in order, to discover what saline and extractive substances they contain ;

contain; and to ascertain their virtues, and the quantities in which they are to be administered.

4. When the ashes of vegetables are deprived, by lixiviation, of all the saline matters which they contained, the residue is nothing but a pulverulent substance, more or less white or coloured, insipid, insoluble in water, and which has been hitherto thought to consist of earths.

The magnet attracts iron from this matter. This iron, as well as the manganese which has in like manner been for some time obtained from this residue of vegetables, must have existed ready formed in the plant. A number of naturalists are of opinion, that plants owe their colours to iron. M. Baumé, who, in his *Memoir on clays*, mentions the earthy residue of vegetables, affirms, that it forms, with the sulphuric acid, alum and sulphate of lime, a little different from that which owes its formation to pure calcareous earth. From this M. Baumé concludes, that the earth of vegetables consists of alumine, and of another earth, nearly of a similar nature with calcareous earths; yet distinct from these, as it does not form quick-lime by the action of fire. He thinks that alumine is formed in these substances by the collisions to which siliceous earth is exposed in them, and by the action of the acids with which it combines; and that alumine, once formed, passes into the state of calcareous earth, in consequence of undergoing new elaborations in the tubes of vegetables.

We cannot help observing in this place, that the discoveries made in Sweden concerning the saline nature of the bones of animals,—which are to animals precisely what the fibrous texture of plants is to vegetable bodies.

dies,—seem to suggest, that the residue of vegetables is any thing rather than an earth. Perhaps an exact analysis, such as has not yet been made, might shew, that what has been taken for an earthy matter, is rather calcareous phosphate; at least we may suspect as much from the experiments of Margraff and M. Berthollet, who have obtained phosphorous from the grains of mustard, from the gluten, and from various other vegetable matters;—as well as from the experiments of M. Hassenfratz, who has extracted phosphoric acid from a great many marsh plants.

C H A P. XXII.

Of Fermentations in general, and of the Spirituous Fermentation in particular.

AFTER considering vegetables in the state in which nature presents them to our observation, we may attend to the alterations and changes which they are liable to suffer from various circumstances: These alterations depending entirely on their nature, are always the effect of a phenomenon, called *fermentation*.

Fermentation is a spontaneous motion which arises in vegetables, and sometimes produces a total change of their properties. This motion is peculiar to the fluids of organic bodies; and no substances, but such as have been elaborated by the functions of vegetable or animal life, are susceptible of it. Chemists have not insisted sufficiently on this important truth, the application of which to the phenomena of organized substances is singularly useful in medicine.

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There must several circumstances concur to promote this fermentation. Such as,

1. A certain degree of fluidity. Dry substances suffer no sort of fermentation.

2. A more moderate or a more intense heat. The degrees of heat vary with the sorts of fermentation ; but cold stops the progress of every kind of fermentation.

Boerhaave, and after him other chemists, have distinguished fermentation into three kinds : Spirituous fermentation, which produces alcohol ;—acetous fermentation, which affords vinegar or acetous acid ;—and putrid fermentation or putrefaction, which produces ammoniac. It is to be observed, that there are several fermenting motions, which cannot be referred to any of these three classes of fermentation.—Such, perhaps, are the fermentations of bread, of insipid mucilages, of colouring matters, &c. It has been thought, that fermentations always succeed each other in the order in which we have mentioned them : but there are bodies which become acid, without passing previously into the state of putrefaction ; and, in other instances, putrefaction takes place without being preceded by the two other species of fermentation.—We may likewise observe, that the internal motion of maturation seems to constitute a species of primary fermentation, which calls forth the saccharine matter from a latent state. It is spirituous fermentation which affords alcohol. In order to become well-acquainted with the phenomena of this species of fermentation, we may consider, 1. The conditions necessary to its productions ; 2. The phenomena which accompany it ; 3. The several matters susceptible of it ;

4. The cause of this internal motion; 5. The product which it forms.

It is well known to chemists, that all vegetable matters are not susceptible of spirituous fermentation, and that, in order to its taking place, several different circumstances must concur. These we are to consider as necessary conditions of spirituous fermentation.

These conditions are,

1. A saccharine mucilage. No other matter is susceptible of spirituous fermentation.

2. A somewhat viscous fluidity. Too fluid a juice is no more susceptible of spirituous fermentation than one that is too thick.

3. The heat of—from ten to fifteen degrees in Reaumur's, or from fifty-five to sixty-five of Fahrenheit's.

4. A considerable mass of matter in which a rapid motion may be excited.

When these four conditions concur, spirituous fermentation then takes place; and certain phenomena invariably accompany it. The following are what have been discovered by observation concerning it.

1. A motion is raised in the liquor, which becomes more and more considerable, till at length the fermentation is fairly established through the whole mass.

2. The bulk of the mixture is considerably enlarged, in proportion as the motion is communicated through the whole mass.

3. The liquor loses its transparency, and is rendered turbid by opaque filaments appearing in motion through all parts of it.



4. There is a heat produced, amounting, according to the Abbé Rozier, to eighteen degrees of Reaumur, or seventy-two and one half, Fahrenheit.

5. The solid parts intermixed with the liquor are raised, and swim, in consequence of the disengagement of an elastic fluid.

6. There is a considerable quantity of carbonic acid gas disengaged. This gas forms a stratum above the liquor in the vessel containing it, which may be easily distinguished from common air. It was on air thus produced, that Dr Priestley and the Duke de Chaulnes made their fine experiments. It extinguishes lights, and proves fatal to animals. It produces from lime-water a chalky precipitate : Caustic alkali it causes to crystallize perfectly. This acid is what renders the employment of those who are engaged in conducting fermentation so very dangerous to health.

7. The disengagement of this gas is attended with the formation of a great many bubbles, which depend on the viscosity of the liquor through which the carbonic acid must pass.

All these phænomena cease by degrees, as the liquor loses its sweet taste and saccharine nature, and becomes brisk, pungent, and capable of producing intoxication.

Men have been taught by necessity to prepare fermented liquors from many different vegetable substances. But experience has evinced, that none but saccharine matters are properly suitable for this purpose. The saccharine matters which are most commonly used in the preparation of fermented liquors, and which therefore best deserve to be examined here, are the following :

1. The juice of the grape, properly so called, produces wine, the best of all fermented liquors. In learning the art of cultivating vines, which is of great importance, it will be proper to examine, 1. The nature of the soil on which the vine grows; a dry parched soil is known to be very favourable to this plant, as it does not thrive well in a strong fat soil:—2. The mode of managing and cultivating this vegetable; it is to be pruned, and its branches bent down, to retard the progress of the sap. Care must be taken to have the vine exposed to the sun, particularly to the reflection of his rays from the ground, &c.; and it does not need to be supplied with any sort of manure, &c.:—3. The history of the vegetation of the vine, its exposure, its flowering, and the formation and ripening of the grape:—4. That of the accidents to which it is liable from frost, rains, moisture:—5. The season of the vintage, which should be dry and hot. When this previous knowledge is acquired, the art of making wine is next to be considered; which consists in putting the grapes, after pulling them, into a vessel exposed to the heat of fifteen or sixteen degrees, and crushing, stirring, and turning them: fermentation is then produced, with all its usual phenomena. The juice of the grape, or must, should not be either too fluid or too thick; when too fluid, it may be thickened by boiling; when too thick, it must be diluted with water. When the wine is made, it is drawn off, and put into open casks. It there suffers insensibly a second fermentation, by which its principles are more intimately combined. It precipitates a fine lee, and a salt known by the name of *tartar*, which we have examined in a former chapter of this volume. To preserve wine,

rags dipped in sulphur are burnt in the cask in which it is contained.

It is farther of importance, to be able to distinguish the different sorts of wine. France produces a great variety of excellent wines : those of Burgundy are the best for constant use : their principles are so perfectly combined, that none is predominant over the rest. The vines of the district of Orleans acquire nearly the same qualities with those of Burgundy, when time has mellowed their harshness, and subdued the excess of spirit or alcohol which they contain. The red wines of Champagne are very excellent, and of a delicate flavour. The white wine of the same country which does not sparkle, is much better than that which sparkles ; for the taste of the latter is tart and sourish ; and it owes its quality of sparkling to its containing carbonic acid, in consequence of having been bottled before the fermentation had been finished. The wines of Languedoc and Guyenne are deep coloured, and highly tonic and stomachic ; especially when old. The wines of Anjou are strongly spirituous, and therefore soon intoxicate. As to foreign wines, those of Germany, known by the name of *Rhenish* and *Moselle* wines, are white, very spirituous, and of a fresh poignant taste : They very soon intoxicate. Some Italian wines, such as those of Orvietto, Vicenza, and Lachryma Christi, &c. are well fermented, and not much inferior to good French wines. Those of Spain and Greece are, in general, sweet, crude, imperfectly fermented, and very unwholesome. We must, however, except those of Rota and Alicant, which are deservedly esteemed very useful stomachics and cordials.

2. Apples and pears afford cyder and perry : These are pretty good liquors ; and M. D'Arcet has shown, that brandy may be obtained from them.

3. Cherries afford a pretty good wine, from which that species of brandy which the Germans call *kirchen-wasser* is extracted.

4. Apricots, peaches, and plums, afford a species not quite so good.

5. Sugar dissolved in water easily ferments. From this sort of wine, prepared from the juice of the cane, there is a spirit extracted, which is known by the names of *taffia*, *rum*, *guil dive*, &c.

6. Gramineous seeds, and of these especially barley, afford a sort of wine, called *beer*. The following are the processes of the art of brewing : The barley is steeped in water for thirty or forty hours, to soften it. It is then laid in a heap, and left in that state till it begin to germinate. It is then dried in a kiln ; and the buds are separated by sifting : after which, it is coarsely ground into what is called *malt*. The malt is put into a vessel, called the *maß-tun*, and hot water poured upon it to dissolve the mucilage. This being drawn off, a second quantity of hot water is poured upon the malt ; and in like manner drawn off. This fluid is called *wort*, and boiled with hops ; after which it is put to ferment, with yeast, into a vessel called the *cooler*. When the fermentation begins to subside, the beer is stirred, and drawn off into casks. The second fermentation throws up a scum called *yeast*, which is kept for fermenting future brewings. Germination calls forth, from a latent state, a certain saccharine matter in barley, to
which

which malt owes its property of affording a wine. A similar liquor might be prepared from most other gramineous seeds.

All these facts concur to show, that the saccharine matter is the only principle of vegetables susceptible of spirituous fermentation, and that water is necessary to the production of this intestine motion. Modern chemists are of opinion, that vinous fermentation consists solely in a change of the proportion of the saccharine principles. A great part of the oxigene combines with the carbonaceous matter, to form the carbonic acid that is disengaged during the fermentation; whilst the hydrogen, combined with a small portion of carbone, forms a very light and subtle combustible body, which contains much less carbonaceous matter than fugar, and is much lighter, and much more inflammable, and constitutes what is called *alcohol*.

The product of all these fermented substances is a peculiar liquor, more or less coloured, of an aromatic smell, of an hot, poignant taste; which, when taken in a small quantity, re-invigorates the fibres, and, when drunk in too great abundance, intoxicates; and is known over all the world by the name of *Wine*.

The wine of grapes, for instance, is a compound consisting of a large proportion of water,—an aroma, peculiar to each different sort of wine,—alcohol,—an essential salt, called *tartar*,—and an extracto-resinous colouring matter, to which red wines owe their colour.

Before proceeding to explain the means by which these principles may be separated, it may be proper to give

some account of the properties and uses of pure unaltered wine. Wine, by means of the water, alcohol, and essential acid salt which it contains, is capable of dissolving a great many bodies. It unites with extracts, resins, certain metals, &c. These are the properties which render wine fit for entering into medical preparations. These preparations are, 1. Emetic wine, which is prepared by macerating four ounces of *crocus metal-lorum* in two pounds of good white wine. The liquor is filtrated, or else made use of in a turbid state, as a powerful stimulus in cases of apoplexy, palsy, &c.—2. Chalybeate wine, prepared by digesting an ounce of iron-filings with two pounds of white wine. It is an excellent tonic and aperient.—3. Vegetable wines, which are prepared, A, either with red wine, in which astringent aromatic plants are macerated; or, B, with Spanish wine. Both the wine of squills, and the liquid ladanum of Sydenham, are prepared with this species of wine. The latter of these is prepared by digesting, for a number of days, two ounces of opium cut into slices, an ounce of saffron, and a drachm of cinnamon and cloves, in a pound of Spanish wine. This mixture, taken in dozes of a few drops, is an excellent calming medicine, especially when there is reason to fear that opium might weaken the patient too much, or might hinder some useful evacuation.

The action of fire is commonly used to decompose wine, and separate its different principles. The liquor is distilled in an alembic of copper plated with tin, with a receiver adapted to it. As soon as the wine is heated to ebullition, it affords a white fluid, in a small degree opaque and milky, of a hot poignant taste, and of

a strong sweet smell. This fluid is collected into the receiver, till such time as the vapours exhaling cease to be susceptible of inflammation at the approach of a candle. This product is what is called *Brandy*: It is a compound of water, alcohol, and a small quantity of oil, which obscures its transparency while it is distilled, and afterwards communicates to it a yellow colour. The colour of old brandy is not, however, owing solely to this oil which passes with it when it is distilled, but rather to the extractive matter of that part of the wood of the casks which it has dissolved. Alcohol, as we shall hereafter see, is extracted from brandy: Wine, after affording brandy, assumes a deeper colour, and a harsh acid taste; it is also turbid, and may be observed to contain a great many saline crystals, which are nothing but tartar. This fluid is now, therefore, totally decomposed, and its original properties cannot be again communicated to it, by combining the spirituous product with the residue: The analysis is therefore complicated. The residue of wine from which brandy has been extracted, takes, by evaporation, the form and consistency of an extract. The colouring part may be separated by alcohol, which does not affect the tartar. This tincture is not liable to be precipitated by water. When evaporated to dryness, the residue readily takes fire, and is soluble in water. It is, in its nature, a true resinous-extractive substance, which the alcohol formed by the fermentation has taken up from the pellicles of the grapes. From this analysis it appears, that wine is actually composed of water, alcohol, tartar, a colouring matter, and an aroma, which is destroyed or modified by the action of fire. We already know the nature and properties

of most of these substances : we have only alcohol to examine.

Before we proceed to speak of this product, it will be proper to say something concerning a substance which is precipitated from wine while it ferments, and is called *lees*. It consists of the seeds and skins of grapes, impure tartar, and sulphate of potash, or vitriolated tartar. Brandy is obtained from it by distillation with naked fire. When treated in a retort, it affords an acid phlegm, and ammoniac ; and its coaly residue contains carbonate and sulphate of potash. The lees of wine, incinerated in the open air, afford caustic potash, mixed with carbonate and sulphate of potash ; a substance known in the arts by the name of *cendres gravelees*. The particulars which we are to relate concerning the properties of alcohol, will complete what has been here said concerning the properties of lees.

Several chemists were of opinion, that the alcohol, in this analysis of wine, was only disengaged by the action of the fire. But if this substance were ready formed in the wine, it would be obtained by a very gentle heat, whilst this can be effected only by ebullition. Thus, modern chemists conceive, that the alcohol is formed by the heat of ebullition, that its principles, *viz.* a large proportion of hydrogen, with a small quantity of carbon, combine together during the distillation of wine ; in short, that this liquor contains only the principles of alcohol.

C H A P.

C H A P. XXIII.

Of Alcohol, or the Product of Spirituous Fermentation.

BRANDY, obtained from wine by distillation with naked fire, is a compound of alcohol, water, and a small portion of oily matter. Distillation is employed to separate these substances, and give the alcohol pure. There are several processes for the distillation of alcohol. M. Baumé recommends the distillation of brandy on a balneum-mariæ, to be repeated as often as may be necessary for the extraction of all the spirit which it contains. He directs, to separate the first fourth part of the product of the first distillation, and, in like manner, the first half of the product of the succeeding distillations; then to mix all these first products together, and rectify them by a gentle heat. The first half of the liquor which passes in this rectification, is the purest and strongest alcohol: the rest is a weaker alcohol, but still better for ordinary purposes. Rouelle directs to extract, by distillation on the water-bath, one half of the brandy made use of: this first product is common alcohol. By recti-
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fying it twice, and reducing it about two thirds of its original quantity, the strongest alcohol is obtained: This, according to Kunckel's process, is to be again distilled with water, to separate the oil by which it is altered. This alcohol, after the distillation with water, is rectified; and the operator is now certain of its being perfectly pure. The residue of distilled brandy is nothing but water impregnated with some particles of colouring matter, with a peculiar oil floating on its surface.

It may be naturally inferred, that this fluid being prepared by various processes, will be, at different times, of different degrees of strength. Attempts have long been made to discover some means of ascertaining its purity. It was at first thought, that the alcohol which burns readily, and leaves no residue, must be very pure: But it is now known, that the heat produced by its combustion is sufficiently strong to dissipate all the phlegm which it may contain. Powder has been proposed as a test of its purity. Alcohol that does not kindle gunpowder, when it is itself kindled, and applied to it in a spoon, is considered as bad; but if it does kindle the powder, it is thought very good. This proof, however, is fallacious; for when any considerable quantity, even of the best alcohol, is poured on a little powder, the water which it affords as it burns, moistens the powder so as to hinder it from kindling; whereas, again, the same powder may be kindled, by burning at its surface a very small quantity even of phlegmatic alcohol. This method of proof is therefore not more certain than the former. Boerhaave gives a very good process for ascertaining the purity of alcohol. It consists in casting dry powdered
potash

potash into the alkali under examination. The potash enters into union with the superabundant water of the alcohol, and forms with it a more ponderous and a higher coloured fluid, which does not mix with the alcohol, but sinks under it. Lastly, M. Baumé, proceeding upon this principle, that the purer alcohol is, so much the more does its levity exceed that of water, has contrived an areometer, by means of which the degree of the purity of this, or of any other spirituous liquor, may be accurately ascertained. When that instrument is immersed in alcohol, the purer the fluid is, so much the deeper does it sink. He has ascertained, by a number of accurate experiments, that the purest and most highly rectified alcohol gives thirty-nine degrees of his areometer, at ten degrees of Reaumur's thermometer. The method of constructing this instrument, with the results which alcohol afforded when mixed with various quantities of water, may be seen in his *Elements of Pharmacy*, and may be applied to determine the strength of spirit of wine by the hydrometer.

Pure alcohol, obtained by the process above described, is a transparent fluid, very moveable, and very light, which weighs six drachms and forty-eight grains, in a bottle containing an ounce of distilled water. Its smell is poignant and agreeable; its taste hot and pungent. It is exceedingly volatile. When exposed even to a slight degree of heat in close vessels, it ascends, and passes unaltered into the receiver. By this means it is concentrated; and any little water which it might contain is separated from it. On this account the first portions are the sweetest, the purest, and the most volatile. It was formerly thought, that there was a good deal of air disengaged

engaged from alcohol when distilled; but what was thought to be air is now known to be the spirituous part of the fluid, which escapes from the water, and is volatilized in the state of gas.

When alcohol is heated in contact with air, it soon kindles, and burns with a light flame, the middle of which is white, and the edges blue: if it has been well dephlegmated, it burns in this manner without leaving any residue. Various chemists have attempted to discover what products alcohol afforded when burnt. They have ascertained, that its flame is not accompanied with any foot or smoke, and that the products volatilized prove to be nothing but pure water, insipid, inodorous, and perfectly in the same state with distilled water. This phenomenon induced Boerhaave to think, that the flame was owing to the water; and his opinion receives confirmation from what is at present known concerning the hydrogenous gas obtained from the decomposition of water,—and concerning the composition of water by the combustion of the same gas with vital air. M. Lavoisier, on burning alcohol in a chimney, which was so constructed and disposed as to collect the vapours, discovered, that the quantity of water obtained is greater than the quantity of alcohol burnt; a fact from which it appears, that alcohol contains a great deal of hydrogenous gas. On the other hand, M. Berthollet has remarked, that when a mixture of alcohol and water is burnt, the fluid residue precipitates lime-water. This experiment shews, that alcohol contains a little carbonaceous matter, which, by its combustion, or combination with oxigene, forms carbonic acid. Chemists have entertained different opinions concerning its nature. Stahl,
Boerhaave,

Boerhaave, and several others, have considered this fluid as a compound of a very subtle oil, with an attenuated acid and water. According to this opinion, therefore, it is a sort of acid soap. Others, at the head of whom Cartheuser and Macquer deserve to be named, think alcohol to consist of phlogiston and water. The true nature of this liquor is not well known ; but it is rather considered as a particular compound, consisting of a large proportion of hydrogene, with a small quantity of carbone.

Alcohol, when exposed to the air, is evaporated at the temperature of ten degrees above the freezing point, and leaves no residue, except a little water, when it has not been sufficiently dephlegmated. The hotter the atmosphere, so much the more rapid is the evaporation. It is attended with a greater or a less degree of cold, according to its rapidity. At 68 degrees of heat above 0 in Reaumur's thermometer, 185° Fahrenheit, alcohol takes the form of an elastic fluid.

Alcohol combines with water in any proportion, and is perfectly soluble in it. This solution is attended with heat, and forms different sorts of brandy, the strength of which is in proportion to the quantity of the alcohol. So strong is the affinity of combination between these two fluids, that water is capable of separating from alcohol many of the other bodies which may be united with it ; and again, alcohol decomposes most saline solutions, and precipitates the salts. On account of its possessing this property, Boulduc has proposed the use of alcohol to precipitate the salts contained in mineral waters, and obtain them without alteration.

Alcohol

Alcohol does not act on pure earths. We know not whether it be liable to be altered by barytes or magnesia. Lime appears to be capable of producing some change upon it; for when alcohol is distilled on this falino-terreous substance, the fluid acquires a peculiar smell. But this phenomenon has not been sufficiently attended to.

The fixed alkalis actually decompose alcohol, as is proved by the preparation known in pharmacy by the name of *acrid tincture of tartar*. In preparing this medicine, a quantity of potash is melted in a crucible, and either pulverized hot, or put into a matrafs: highly dephlegmated alcohol is poured to three or four finger depth above the salt: the matrafs is closed with another of a smaller size: these are luted together, and the whole is digested on a sand-bath, till the alcohol acquire a reddish colour. Either more or less alkali remains at the bottom of the vessel. By distilling the acrid tincture of tartar, we obtain an alcohol of a sweet smell, but little altered; and there remains in the retort a matter resembling a saponaceous extract, which, when distilled by naked fire, affords alcohol, ammoniac, and a light empyreumatic oil. After this operation, a little charcoal remains, which is found to contain the potash. From this experiment it would appear, that alcohol contains or forms an oil, which the fixed alkali seizes, and forms with it a real soap that is found in the portion of the alcohol which has not suffered decomposition. The *tillium of Paracelsus* differs from the acrid tincture of tartar, only in that the fixed alkali employed in the preparation of it appears to have been reduced to a caustic state by the metallic oxides with which it was heated.

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The *martial*, *jovial*, and *cupreous* reguli of antimony, of each four ounces, are fused together, reduced to powder, and detonized with eighteen ounces of nitre, and as much tartar : they are urged with fire till they melt ; the mixture is then pulverised, put into a matrafs, and highly dephlegmated alcohol poured upon it, to the depth of three or four fingers breadth above the powder. This mixture, digested on a sand-bath, assumes a beautiful red colour, deeper than that of the acrid tincture of tartar, and exhibits all the same phænomena. That tincture may be rendered entirely similar to the *lilium* of Paracelsus, by digesting alcohol on caustic fixed alkali, instead of using fixed salt of tartar, which is not entirely deprived of its carbonic acid by the action of fire, unless it be kept for a long time red-hot. M. Berthollet is convinced that these tinctures are nothing but solutions of caustic potash in alcohol, and they afford an happy mode of obtaining this alkali very pure, as they leave it separate by evaporation. Alcohol acts in the same way on pure soda. The acrid tincture of tartar, and the *lilium*, are very good tonics, and powerful discutives. They are employed in all cases in which the natural strength of the patient is not sufficient to support the progress of his disease to a crisis, as in the malignant fever, small-pox of a bad kind, &c.

The action of caustic ammoniac on alcohol has not yet been examined.

All the acids exhibit with alcohol phænomena highly worthy of observation. When a quantity of strongly concentrated sulphuric acid is poured on an equal quantity of rectified alcohol, a remarkable heat and hissing take place. The two substances become coloured ; and

there is at the same time exhaled from them a sweet smell, resembling that of lemons, or the apple called the *golden rennet*. If the retort in which this mixture is usually made be placed on a hot sand-bath, with two large balloons adapted to it, the first being immersed in a vessel full of cold water, the products obtained are,

1. A sweet-smelling alcohol.
2. A liquor called æther, of a very sweet smell, extremely volatile, and whose presence is indicated by the ebullition of the liquor contained in the retort, and by the large striæ with which the sides of the vessel are furrowed. Care must be taken to cool the receiver with wet cloths.
3. After the æther follows sulphureous acid, the white colour and smell of which shew that it is time to change the receiver, in order to obtain the æther separate.
4. There is at the same time volatilized a light yellowish oil, which is called *sweet oil of wine*. The fire must be greatly moderated after the æther has passed; because the matter now remaining in the retort is black and thick, and swells considerably.
5. When the sweet oil is all distilled, there likewise passes sulphureous acid, which becomes gradually thicker, till at last it is nothing but black and dirty sulphuric acid.
6. Continuing this operation by a moderate fire, the residue is at length so much dried as to take the form and consistency of a bitumen. This bitumen exposed to a very strong fire, affords an acid liquor, and a dry yellowish substance like sulphur.

M. Baumé, who has made a long train of experiments on sulphuric æther, has examined this residue with a great deal of care: He has found in it sulphate of iron, Prussian blue, a saline substance, and a peculiar earth, the nature of which he has not determined.

mined. He even asserts, that the yellow sublimate which it affords is not sulphur; and that it remains white and pulverulent, without being kindled on the coals. To these particulars we shall add, that a new quantity of æther may be obtained from the residue from which æther has been once obtained, by adding to it, according to M. Cadet's process, one third part of alcohol dephlegmated by potash, and distilling that mixture. These distillations may be several times repeated; so that from a mixture of six pounds of sulphuric acid with alcohol, by adding to it successively fifteen pounds of the latter of these fluids, more than ten pounds of good æther may be obtained.

The operation which we have been describing is, by the phenomena which it presents, one of the most singular, and at the same time one of the most important, in all chemistry, as it affords some information concerning the principles of which alcohol is composed. There are two opinions concerning the formation of æther; of which it is proper for us to give some account. Macquer, who, as has been mentioned, thinks alcohol a compound of water with phlogiston, is of opinion, that in the formation of æther, the sulphuric acid, seizing the water of the alcohol, brings it nearer in nature to oils. Thus, according to this opinion, there passes, at the first, alcohol a little altered;—then a fluid of a middle character between alcohol and oil, which is æther;—and, lastly, a genuine oil; because the stronger the heat employed to obtain the æther, with the greater energy does the sulphuric acid act on the principles of the alcohol. Bucquet, struck with a strong objection which he made to this theory, namely, its being hard to

conceive how the sulphuric acid, impregnated as it must be, from the time when it begins to act upon the alcohol, with a certain quantity of water, abstracted from that fluid, can, notwithstanding this dilution, re-act with such force on another part of the same alcohol, as to reduce it into an oily state,—has advanced another opinion concerning the production of æther. He considered alcohol as a fluid compounded of oil, an acid, and water; He thought, that when the sulphuric acid was mixed with alcohol, the result of the mixture was a sort of bituminous fluid, which afforded by heat the same principles with all the other bitumens,—that is to say, a light oil, very odorous, and highly combustible; a sort of naphtha, which was æther; and then an oil, less volatile, but higher coloured than the former, which is the sweet oil of wine. We will in fact see, in examining the properties of æther, that this fluid has all the characteristics of a very subtle oil, such as naphtha. This theory does not afford a sufficiently clear explanation of what passes in the preparation of æther. It appears, that the alcohol deprives the sulphuric acid of its oxigene;—that a part of the hydrogenous principle contained in the alcohol, combines with this oxigene to form water;—and that the alcohol, after losing that part of its hydrogen, forms æther. But we are not acquainted with all that passes in this operation.

Æther, obtained by the process here described, is not very pure: It is combined with alcohol and sulphurous acid. To rectify it, it is distilled in a retort, on a sand-bath, with fixed alkali. This salt combines with the sulphureous acid, and the æther then passes very pure by the most moderate heat. By separating the first half
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of this product, the æther is obtained in the purest and most highly rectified state.

Æther is a fluid lighter than alcohol, of a strong sweet smell, susceptible of great expansion, and of a hot and pungent taste. It is so volatile, that when stirred or shaken, it is dissipated in an instant. When evaporating, it produces a cold sufficient to freeze water, as M. Baumé has shewn by his beautiful experiments. It is reduced into a sort of æthereal gas, which burns with rapidity. Air in which æther is contained, in a state of solution, will pass through water without losing its odour or inflammability. Æther is very easily kindled, by being heated in the open air, or brought into contact with a burning body; the electric spark likewise kindles it. It displays a very luminous white flame, and leaves a black, and seemingly carbonaceous, mark on the surfaces of bodies exposed to its flame. M. Lavoisier has proved, that carbonic acid is formed during the combustion of this liquor; and M. Scheele, that the residue of æther burnt on a little water contains sulphuric acid.

Æther, according to the Count de Lauraguais, is dissolved in ten parts of water. The phænomena which æther is capable of exhibiting with saline substances, have not yet been particularly examined. We know only how it re-acts on acids. Lime and the fixed alkalis do not appear capable of producing any alteration upon it. Caustic ammoniac mixes with it in all proportions, forming with it a matter, the mixed smell of which might produce very happy effects in spasmodic complaints. The sulphuric acid becomes considerably hot with æther, and is capable of converting a great part of it into sweet oil of wine, by distillation. The fuming ni-

trous acid excites a considerable effervescence in æther; and æther appears to become higher coloured, and more oily, and to acquire greater consistency, in consequence of the admixture of this acid. When mixed with the muriatic solution of gold, æther retains a part of the metal, acting, it would appear, in the same way as volatile oils, which also retain a part of the oxide of gold. It dissolves volatile oils and resins, like alcohol: And physicians often make use of æthereal tinctures.

Æther is thought a powerful tonic, and a very good antispasmodic medicine. It is administered in hysterical complaints, and in spasmodic colics. It acts very speedily in promoting digestion, when this is retarded by a weakness of the stomach. It must, however, be administered with prudence, for it is known to be dangerous when taken in too great quantities. It is also applied externally, with very happy effects, to remove the headache, and cure burnings, &c. Hoffman, who paid much attention to the combinations of alcohol with the sulphuric acid, made use of a medicine consisting of sweet oil of wine, dissolved in alcohol, which he called his *anodyne mineral liquor*. The Faculty of Medicine of Paris have added æther to this liquor, and have, in their Dispensary, directed it to be prepared by mixing two ounces of alcohol, which passes before the æther, two ounces of æther, and twelve drops of sweet oil of wine. This medicine is employed in the same way as æther, but is greatly inferior in its effects.

The nitric acid acts upon alcohol with great rapidity. Navier of Chalons is the first who has given an easy and not very expensive process for the preparation of nitric æther. His process is as follows:—Into a very
strong

strong bottle of the manufactory of Séves, pour twelve ounces of very pure and highly rectified alcohol, and immerse it in cold water, or rather in pounded ice : at several different times, stirring the mixture each time, add eight ounces of concentrated nitric acid : then close up the bottle with a good cork, covered with leather. Set this mixture aside, in some private place, to avoid accidents from the bursting of the bottle,—which sometimes happens. In a few hours, bubbles arise from the bottom of the bottle, are collected in drops on the surface of the liquor, and form, by degrees, a stratum of genuine æther. This phenomenon continues to go on for four, or from four to six days. As soon as the motion of the liquor appears to have ceased, the cork must be pierced with a pin, in order to the emission of a certain quantity of gas, which would otherwise force its way out by uncorking the bottle, and carry with it all the æther. When this gas is discharged, the bottle may be unstopped, the liquor contained in it poured into a funnel, stopping the under end of the funnel with the finger, and the supernatant æther separated from the residue, and received into a glass phial.

Mr Woulfe has given a different process for the preparation of nitrous æther. He uses very large vessels, which afford room for the reception of the air that is disengaged. Taking a balloon of clear glass, sufficiently capacious to hold eight or ten pints, and terminating in a neck seven or eight feet long, he places it on a tripod, high enough to receive under it a chafing-dish. The neck of the matrafs is to be adjusted to a tubulated capital, with a glass tube seven or eight feet long, adapted to its beak. The lower extremity of the tube is received

into a balloon with two necks, the lower part of which is drawn out into a tube, and inserted into a bottle. The other neck of this balloon joins the bottles composing Woulfe's apparatus, which we have already repeatedly described. When all these vessels are sufficiently luted together, a pound of rectified alcohol, and as much fuming nitrous acid, is to be poured into the matrafs, through the hole perforated in the capital: this hole must then be stopped with a crystal stopper, wrapped in a piece of leather. The mixture becomes immediately exceedingly hot: vapours are disengaged, and pass rapidly along the neck of the balloon; and this vessel being exposed to a heat sufficient to boil the liquor which it contains, a quantity of nitric æther passes into the balloon employed as a receiver. This process, though very ingenious, is attended with several inconvenient circumstances: It takes a long time to set up the apparatus which is both very expensive and very troublesome: and it still exposes the operator to danger; for notwithstanding the room afforded in the vessels for the reception of the vapours, yet, so rapidly are they disengaged, that the vessels happen to be pretty often burst, with considerable noise.

M. Eogues, in the year 1773, published another process for preparing nitric æther. He directs to mix, in a glass retort, capable of containing eight pints, a pound of alcohol with a pound of nitric acid, weakened so as to exhibit only twenty-four degrees of M. Baume's hydrometer;—to adapt to the retort a balloon of the capacity of twelve pints;—to afford a passage to the air, by inserting, at the juncture of the lute, the barrels of two quills;—and to distil the mixture by a very moderate

rate

rate heat, taking care that the retort sink but a little way in the sand-bath. By this means he obtained six ounces of nitric æther, of sufficient purity. It appears, from what the Abbé Rozier has said, that Mitouard followed, since the year 1770, a process nearly similar to that communicated to the public by M. Bogues. That chemist subjected four ounces of fuming spirit of nitre, with twelve ounces of alcohol, to distillation in a retort: He placed the retort gently on the sand-bath; and by this means, which appeared to him simpler than any other that had been recommended, he obtained a quantity of nitric æther, of the same kind with M. Navier's. Lastly, M. de la Planche, apothecary at Paris, has contrived two different ways of preparing nitric æther, each of which has its conveniences. The first consists in putting nitre into a tubulated stone retort, with a large balloon, and pouring in by the aperture, first, concentrated sulphuric acid, and afterwards alcohol. The sulphuric acid disengages spirit of nitre, which re-acts upon the alcohol, and forms, almost instantaneously, nitric æther. As æther prepared in this way might be suspected to be partly sulphuric, he afterwards adopted, in preference to this method, a new process; which is indeed exceedingly ingenious: To a tubulated glass-retort, into which he had put six pounds of dry nitre, he joined an adapter, and a receiver, communicating by a curved tube with an empty bottle. The bottle, again, by means of a syphon, communicated with another bottle, containing three pounds of the best alcohol. Then, after properly luting the whole of this apparatus, and placing the retort on a cinder-bath, he poured upon the nitre, through the aperture in the retort, three pounds of concentrated

fulphuric acid,—shut up the retort with a crystal stopper, urged it with fire, till it was raised to ebullition,—and maintained it in that state, till it ceased to emit vapours. On this occasion, the sulphuric acid disengages the acid of nitre, one part of which passes into the receiver, and the rest into the second flask. At the end of the operation, the receiver contains fuming nitrous acid, the retort sulphate of potash, and the second bottle an æthereal liquor. This æthereal liquor is next distilled in a retort, with a single balloon, and only two thirds of the product taken up. This product is distilled with a fifth part of fuming nitrous acid, gradually poured upon it, through a long glass funnel: of this likewise no more than two thirds are distilled off. Lastly, This second product is rectified on potash; four ounces are, at the first, taken off; and then the remaining three fourths. The four ounces are very pure nitric æther; and the remaining three fourths a nitrous, anodyne mineral liquor. The residues of these two rectifications are dulcified spirit of nitre.

The nitric æther obtained by these processes is a yellowish fluid, equally volatile and susceptible of evaporation with sulphuric æther. Its smell is nearly the same with that of sulphuric æther, but rather stronger, and not so pleasant. Its taste is hot, and more disagreeable than that of sulphuric æther. It contains a small quantity of superabundant acid. It causes the corks to start from the phials in which it is inclosed; a large quantity of gas being constantly disengaged from it. It burns with a brighter flame, and a thicker smoke, than sulphuric æther, and does not leave just so large a proportion of carbonaceous residue. Lastly, like sulphuric æther, it
takes

takes up gold from a solution of that metal, and becomes charged with a certain quantity of it.

The residue of nitric æther is of a lemon-yellow colour; its smell is acid and aromatic; its taste pungent, like that of distilled vinegar. According to M. Baumé, it affords, by distillation, a clear liquor, the smell of which is sweeter than that of nitric æther, and its taste an agreeable acid. It reddens syrup of violets, combines with water in any proportion, and effervesces with carbonate of potash. There remains in the retort, after this liquor is distilled off, an amber-yellow matter, friable, and similar in its appearance to real amber, which attracts moisture from the atmosphere, becomes pitchy while it continues exposed to it, and dissolves in water without rendering it mucilaginous. This substance, which M. Baumé calls gummi-saponaceous, affords in the retort a few drops of an acidulated liquor, which is very clear, of an oily consistency, and a light empyreumatic smell. After the distillation, there remains a spongy coal, which is brilliant, insipid, and very obstinately fixed in the fire. Bucquet says, that the liquor which remains after the formation of nitric æther, takes, by evaporation, a mucilaginous consistency; and that, in a longer or a shorter space of time, there are saline crystals formed in it, which bear a considerable resemblance to hairy caterpillars, and are called *crystals of Hiærne*, from the name of the chemist who gave the first description of them. This residue has been discovered to be oxalic acid; and the radical principle of that acid appears therefore to be contained in alcohol.

The muriatic acid does not act in any perceptible manner on alcohol. This acid is only dulcified by simple

mixture with this liquor, as are also the two others, when mixed in a small proportion with alcohol. M. Baumé, in his Dissertation on æther, mentions his having obtained a little muriatic æther, by bringing vapours of muriatic acid into contact with vapours of alcohol.—Ludolf and Pott employed sublimated muriate of antimony with this view. Baron Bornes directs to dissolve oxide of zinc in muriatic acid, and to distil that salt, after concentrating it by evaporation in close vessels with alcohol. This is an easy enough way of obtaining muriatic æther. But no body has paid so much attention to this object as the Marquis of Courtanvaux. His process is, to pour into a glass-retort a pint of alcohol, with two pounds and a half of muriate of tin, or *fuming liquor of Libavius*. A very strong heat is thus excited; and there arises a white suffocating vapour, which disappears when the mixture is stirred. An agreeable smell then exhales from it, and the liquor takes a lemon-colour. Place the retort on a hot sand-bath: join to it with luting two balloons; and let the most distant of the two be immersed in cold water. The first product which passes is dephlegmated alcohol; after it the æther ascends. The ascent of the æther may be distinguished by its sweet smell, and the stræ which it forms on the sides of the retort. When the smell changes, and becomes strong and suffocating, the receiver must be changed, but the distillation still carried on. The product now obtained is first a clear acid liquor, with some drops of mild oil swimming on its surface; next, a yellow matter, of the consistency of butter, which is a true muriate of tin; and lastly, a brown ponderous liquor, which exhales a considerable quantity of white vapours.—There
remains

remains in the retort a grey pulverulent matter, an oxide of tin. The æthereal product must now be poured into a retort upon a quantity of potash: The phenomena which follow are, a lively effervescence, and a copious precipitation, both owing to the tin which the acid has carried up with it when distilled. By adding a little water, and distilling the contents of the retort by a moderate heat, a product is obtained, equal to about one half of the former æthereal product. All the liquors which pass after the muriatic æther are strongly impregnated with oxide of tin: They attract moisture from the atmosphere, and combine with water, without affording any precipitate. It was not known to what cause the rapidity with which the muriatic acid contained in the fuming liquor acts upon alcohol, while the pure acid does not act upon it at all, should be ascribed: but from a discovery of Scheele's, it appears that it is owing to the acid being then in the state of oxygenated muriatic acid, in consequence of which the excess of oxigene which it contains converts the alcohol into æther. This theory was first advanced by myself, in the year 1781; and has been since confirmed by the experiments of Messrs Berthollet and Pelletier.

M. de la Planche, apothecary, has proposed the preparing of muriatic æther, by pouring into a tubulated retort sulphuric acid and alcohol upon decrepitated muriate of soda. The muriatic acid gas, disengaged by the sulphuric acid, upon entering the receiver, comes into contact with the alcohol in a vaporous state, and combines with it. The result of the combination is, an æthereal acid, which, by rectification on fixed potash, becomes pure æther. It appears, that in this process the
muriatic

muriatic acid deprives the sulphuric acid of a part of its oxigene.

Muriatic æther is highly transparent and volatile. It has nearly the same smell with sulphuric æther. It burns in the same way, and affords a similar smoke. It differs from it, however, in two properties : Muriatic æther exhales, as it burns, an odour equally pungent and lively with that of the sulphureous acid ; and it has a stiptic taste, like alum. These two phænomena indicate this æther to be of a different nature, and possibly less perfect than the two preceding sorts of æther. No doubt, when its properties are more minutely examined, it may be found distinguished by other more remarkable peculiarities.

After this account of the manner in which these three mineral acids act upon alcohol, we are to proceed with the history of this fluid. Little attention has been paid to the action of the other acids on alcohol. We know only, that it combines readily with the boracic acid ; that in consequence of combination with this acid, it burns with a green flame ; and that alcohol absorbs a quantity of carbonic acid gas, more than equal to its own bulk. As to the neutral salts, Macquer has ascertained, that this spirit dissolves sulphuric neutral salts, but with great difficulty ; that nitric and muriatic salts combine with it much more readily ; and that the less intimately the acid is combined with the other principle of these substances, the more of them does the spirit usually dissolve. Alcohol, boiled on sulphate of potash and soda, dissolved none of either of these neutral salts. Neither does carbonate of potash, or of soda, unite with it : Most ammoniacal salts combine with it.

Deliquescent earthy salts, such as calcareous and magnesian nitrate and muriate, dissolve very readily in it. Some metallic salts are also very soluble in alcohol ; such as, sulphate of iron in mother-water, nitrate of copper, muriate of iron and of copper, oxygenated muriate of mercury, or corrosive sublimate. All cupreous salts cause alcohol to burn with a beautiful green flame. M. de Morveau has since given a fuller table of the different degrees in which salts are soluble by alcohol, which is inserted in the *Journal de Physique*.

Alcohol does not dissolve sulphur, either in masses or in a powder ; but these two bodies unite, if brought into contact when they are both in a vaporous state, as has been discovered by the Count de Lauraguais. His process consists in putting sulphur in powder into a glass-cucurbite, putting into the same vessel, above the flowers of sulphur, a bottle filled with alcohol, and heating the cucurbite on a sand-bath, with a capital and a receiver adapted to it. Both the sulphur and the alcohol are volatilized at the same time : They combine, and pass into the receiver, in a fluid which is somewhat turbid, and diffuses a foetid smell. It contains about a grain of sulphur to the drachm of alcohol. I have discovered that the same combination may be produced by distilling sulphureous waters, such as the water of Engbien, with alcohol.

Ardent spirit, or alcohol, does not act at all on either metallic matters, or their oxides. It dissolves amber in part. It produces no effects on black carbonaceous bitumens. It is observed, that it combines best with amber, after being distilled on fixed alkali, and that fixed alkali, mixed with this bituminous substance, renders it

much more soluble, by reducing it, no doubt, to a saponaceous state.

There are few vegetable matters on which alcohol does not act with more or less energy. It destroys the colouring part, and frequently the whole substance of extracts, when they are of an extracto-resinous, or a resino-extractive nature: the saccharine and saponaceous extracts combine with this fluid. Margraff has obtained, by alcohol, a saccharine essential salt from red beet, *kirret*, parsnip, &c. But the matters with which it combines the easiest are volatile oils, the aroma, camphor, balsams, and resins. Alcohol impregnated with the aroma of plants, is improperly called *distilled spirituous waters*. To obtain these fluids, distil alcohol on a *balneum-mariæ* with odorous plants. The liquid takes up the odorous principle, and is volatilized with it, carrying off, at the same time, a certain quantity of volatile oil, which causes it to become white with distilled water: But the oleaginous principle may be separated, by rectifying it on a water-bath by a very moderate heat; and care must be taken, that no more than three fourths of the alcohol employed be drawn off, lest some other substance besides the aroma should be volatilized with it. The smell of these distilled spirituous waters becomes more and more agreeable as they grow older; and it appears, that the odorous principle combines more intimately with the alcohol the longer they are in union.

So great is the affinity between the aroma and alcohol, that alcohol detaches it from volatile oils and water.—When alcohol is distilled on volatile oils, and on water impregnated with the odorous principle of a plant, the
alcohol

alcohol seizes the odorous principle, leaving the oil and the water destitute of smell. It is observed, that alcohol dissolves thick and ponderous volatile oils, more readily than such as are very light and fluid. Water separates the principles of this compound : It precipitates the oil in the form of opaque white globules ; but the aroma still remains combined with the alcohol. This liquid easily dissolves camphor in a cold state ; but it dissolves still a greater quantity of it when assisted by the action of heat. This solution, in the proportion of two drachms of camphor to the ounce of alcohol, with water added, drop by drop, affords a crystalline vegetative figure, which has been observed by M. Romieu : It is a perpendicular filament, with needles rising upon it, under an angle of sixty degrees. This experiment succeeds but seldom ; as it is so very difficult to employ precisely the proper quantity of water, the proper degree of cooling, &c.

Compounds of oily or resinous juices with alcohol, in which the alcohol is so strongly charged with the oleaginous or resinous juice, as to be coloured by it, and to afford a copious precipitate in water, are called *tinctures*, *elixirs*, *balsams*, *quintessences*, &c. Like distilled spirituous waters, these are either simple, as when there is only one matter dissolved in them ; or compound, when they contain several matters together. These medicines are generally prepared by exposing the juice in powder, or the dry plant, the volatile oil or resin of which is to be dissolved, to the action of alcohol, assisted by stirring, and by the gentle heat of the sun or a sand-bath. To extract the resins, or any other vegetable matters, from several different plants at once, care must be taken, first

to digest the matter which is the least liable to be affected by the action of the alcohol, and then to expose to it, successively, the other substances over which it has greater power. When the menstruum is charged with as much of these matters as it can receive, it is strained off. Sometimes a compound tincture is prepared at once, by mixing together several simple tinctures. In this manner, the *elixir proprietatis* is prepared, by mixing the tinctures of myrrh, saffron, and aloes. Resins and balsams may be separated from alcohol by pouring water upon the tinctures, or distilling them; but in either of these cases, the alcohol retains the odorate principle. Water is not capable of decomposing tinctures formed with extracto-resinous, or resino-extractive matters, such as those of rhubarb, saffron, opium, gum-ammoniac, &c.; for these matters are equally soluble in both the menstrua.

Alcohol and brandy are very generally used, and applied to a great variety of purposes. The last of these liquors is drunk as a cordial, to revive the exhausted spirits; but in excess it is dangerous, for it dries up the fibres, and occasions shaking, palsy, and dropsy. Alcohol, either pure or mixed with camphor, is used to stop, by external application, the progress of gangrenes.

Distilled spirituous waters are administered in medicine, as tonics, cordials, antispasmodics, stomachics, &c. They are given either diluted in water, or sweetened with syrups.

Of these waters with sugars, there are certain drinks prepared, which are known under the name of *ratasias*, or *liqueurs*. These drinks, when properly prepared, and taken in small quantities, may be of service; but they
commonly

commonly agree with very few people, and are hurtful to very many. These liquors, taken in excess, are extremely dangerous to the human constitution. Instead of invigorating with new strength, and fortifying the tone of the stomach, as they are commonly thought to do, they produce most frequently a quite contrary effect. Those which, drunk but seldom, and with great moderation, are the least injurious, are prepared cold, with one part of alcohol distilled upon the aromatic substance which is to afford the flavour, two parts of water, and one of the finest sugar.

Tinctures have nearly the same virtues with distilled spirituous waters, but they act with much more energy; and therefore they are to be used in much smaller quantities, and given in wine, in potions, and even in aqueous liquors. The precipitate which they yield in the last of these, is equally suspended through the mixture, and besides the odorous part remains dissolved in the alcohol.

Lastly, Alcohol combined with the copal resin, with oil of aspic, or the greater lavender, or with oil of turpentine, forms *varnishes*, which are called *drying*; because, when a coat of this compound is laid on any body to varnish it, the alcohol is soon volatilized, and leaves on the varnished body a transparent resinous plating. The volatile oils, which are mixed with this composition, hinder the varnish from drying too hastily, and, by communicating to it somewhat of an unctuous nature, render it less brittle than it would otherwise be.

C H A P. XXIV.

Of Acetous Fermentation, and of the Acetous and the Acetic Acids.

MANY vegetable substances are susceptible of acetous fermentation. Of this kind are gums, and amylaceous fæcula dissolved in boiling water ; but spirituous and fermented liquors possess this property in the most eminent degree. Acid fermentation may be excited in any of these fluids, by exposing them to the action of heat and air at the same time, so as to convert them into what is called *vinegar*. This liquor is chiefly prepared from the wine of grapes ; but very good vinegar might be also prepared from cyder, perry *, &c.

There are three conditions necessary to vinous fermentation : 1. A heat of twenty or twenty-five degrees of Reaumur's thermometer, or from 75° to 90° of Fahrenheit's : 2. A substance at once viscous and acid, such as mucilage and tartar : 3. The contact of air. The change

* Vinegar is made in Britain from wort, the infusion of malt.

change which wines undergo, when converted into vinegar, can be attributed to nothing but an intestine motion, excited in those bodies in consequence of their containing a certain quantity of mucilaginous matter, unaltered, and still susceptible of another fermentation. The presence of an acid matter, such as tartar, is requisite to produce acid fermentation. Lastly, The contact of air is indispensibly necessary ; and it appears,—it has indeed been proved by the Abbé Rozier, that the liquor absorbs a portion of air while it ferments ; this is probably oxigene.

All kinds of wine are equally good for making vinegar. The worst are preferred, because they are the cheapest. But the experiments of Beccher and Cartheuser shew, that generous wines, not destitute of spirit, afford generally the best vinegar.

Boerhaave, in his *Elements of Chemistry*, has given a very good process for the preparation of vinegar. Take two casks : at some distance from the bottoms of these casks, form within each of them a false bottom of wicker-work : upon this false bottom spread grape-stalks and vine-branches ; pour upon these wine, till one of the casks be entirely full, and the other half-full. The fermentation will first begin in the latter : when it is fairly commenced, fill up this cask with wine from the other : by this means, the fermentation is moderated in the full cask, and begins in the other. After it has continued for a due length of time, fill up the latter cask again, from the cask in which the fermentation first began :—thus the fermentation is again excited in the former, and becomes languid in the other. The two casks are to be thus successively filled up and emptied, till such

time as the vinegar be entirely formed ; which is not, usually, in less than fifteen days.

In observing the phenomena of this fermentation, we perceive a good deal of boiling and hissing :—The liquor becomes hot and turbid ; and a great many bubbles and filaments appear to run through it in all directions : there exhales from it a lively acid smell, which is in no way dangerous : it absorbs a great deal of air. There is a necessity for stopping the fermentation every twelve hours : by degrees these phenomena disappear ; the heat falls, the emotion ceases, and the liquor becomes clear. It deposits a glareous sediment, in reddish flakes, which stick to the sides of the casks. It appears, from a sufficient number of experiments, that the smaller the quantity of the wine, and the more it is exposed to the contact of air, so much the more readily does it pass into the state of vinegar. Care must be taken to draw off the vinegar clear, when it is thus prepared, in order to separate the lee, which, were this precaution neglected, would cause it to pass into the state of putrid fermentation.—Vinegar does not, like wine, deposit tartar by rest : this salt was dissolved, and combined with the alcohol and water, during the fermentation. It is even probable, that the presence of this salt has a principal influence in calling forth the properties of vinegar from a latent state. This vinegar is of a lighter or a higher colour, according to the nature of the wine from which it is prepared : but even the lightest coloured vinegar is generally much higher coloured than any sort of white wine ; because the colouring part of the tartar, which has been called forth from a latent state by the production of the acid, is dissolved in it.

Vinegar

Vinegar prepared in the manner above described is extremely fluid, of an acid spirituous smell, and of a taste in a greater or a less degree sour. It reddens blue vegetable colours. When exposed to a moderate heat, in vessels indifferently stopped, it is altered, loses its spirituous part, deposits a great deal of mucilaginous flakes and filaments, and assumes a putrid taste and smell. M. Scheele has shewn, that it must be boiled for a few minutes, in order that it may be preserved unspoil.

When vinegar is distilled by naked fire, in a stone cucurbit covered with a capital, or in a glass retort on a sand-bath, it affords a phlegm of a lively and agreeable smell, scarcely acid; to which immediately succeeds a very white, and strongly odorous acid liquor: this is distilled vinegar: What follows is less odorous, but more acid; and the farther the process advances, the more acid does the product become.—These several products may be taken separately; by which means, so many different sorts of distilled vinegar will be obtained, of various degrees of acidity and smell. The operator must be satisfied with obtaining two thirds of the liquor, which forms the purest vinegar. The portion which passes after this, is more acid; but it has an empyreumatic smell, which may be removed by exposing it to the air. It likewise acquires a faint colour. This operation shews the acetous acid to be more ponderous than water. The residue is thick, and of a dirty, deep-red colour. It deposits a certain quantity of tartar, and is in an high degree acid.—Evaporated over an open fire, it takes the form of an extract; and if, when dry, it be distilled in a retort, it affords an acid reddish phlegm, an oil which is at first light and coloured, but becomes after-

wards ponderous ; with a little ammoniac.—The residual coal, now left, contains a considerable proportion of fixed alkali.

Vinegar may be concentrated by exposing it to frost.—That portion which still remains liquid becomes highly acid, and is decanted off. The frozen part is almost entirely water. Only a very little vinegar is obtained by this operation.

The acid of vinegar, when separated from tartar and from its colouring part by distillation, is susceptible of combination with a great number of bodies.

It combines only in an imperfect manner with aluminous earth, and forms with it needled crystals, the properties of which are but very little known. The name of this salt (in the new Nomenclature) is *Acetite of alumine*.

It combines readily with magnesia, affording in the combination a salt, which is extremely soluble in water, and does not crystallize, but affords, by evaporation, a viscid, deliquescent mass. Acetite of magnesia is decomposable by fire, by mineral acids, by barytes, by lime, and by the three alkalis.—It is very soluble in alcohol.

The acetous acid combines with lime ; and decomposes chalk, disengaging its acid in the form of an elastic fluid.—The salt which it forms with lime crystallizes into very fine needled crystals, of a glossy appearance, like satin.—Calcareous acetite is sour and bitter : it effloresces in the air. It is decomposed by fire ; by fixed alkalis, which separate the earth ; and by mineral acids, which disengage the acid.

The

The combination of the acetous acid with potash, is improperly called, in the laboratories, *foliated earth of tartar*: it should be denominated, *acetite of potash*. In preparing this salt, a quantity of very pure distilled vinegar is poured upon carbonate of potash, prepared by the incineration of tartar; the mixture is stirred, and vinegar is poured in, till the salt be fully dissolved, and the two substances mutually saturated:—there should rather, indeed, be an excess of the acid.—This liquor is filtrated, and evaporated by a very moderate fire, in a vessel of porcelain or pure silver. When it becomes thick, the evaporation is continued on a water-bath till it be quite dry. By this means a very white salt is obtained.—If exposed to too much heat, it takes a grey or a brown colour, because a portion of the vinegar is burnt.—Some chemists affirm, that acetite of potash may be obtained in a regular form, by suffering the solution to cool after having evaporated it to a thick pellicle.

Acetite of potash is of a pungent, acid, urinous taste.—By the action of fire it is decomposed, so as to afford, in the retort, an acid phlegm, an empyreumatic oil, ammoniac, and a large quantity of strong smelling gas, consisting of carbonic acid, with hydrogenous gas. The residual coal contains a good deal of naked potash.—This salt strongly attracts the moisture of the atmosphere, and is very soluble in water. The sulphuric acid decomposes it. To effect this decomposition, one part of concentrated sulphuric acid is poured on two parts of acetite of potash, introduced into a tubulated glass-retort, with a receiver fitted to it. There is instantly disengaged, with a lively effervescence, a vaporous fluid,

of a poignant smell, which, in the receiver, condenses into acetic acid, the *radical* principle of *vinegar*. This vinegar is highly concentrated, and strongly acid, but not pure, and always mixed with a certain quantity of sulphureous acid, which may be distinguished by its smell.—The tartareous acidulum likewise decomposes acetite of potash; because it has a nearer affinity than the acetous acid with the alkaline base of this salt.

Vinegar enters into a perfect combination with soda, and forms with it a salt which has been improperly called *crystallizable foliated earth*: We give it the denomination of *acetite of soda*. The only difference between this salt and acetite of potash, is, that it crystallizes in striated prisms, much like those of sulphate of soda, and does not attract moisture from the atmosphere. To obtain it in regular crystals, its solution must be evaporated to a pellicle, and then set in a cool place. Acetite of soda, like acetite of potash, is decomposable by fire, and by mineral acids. To these particulars we may add, that when alkaline acetous salts are distilled by a strong fire, the residues which they leave are so many pyrophori, and burn when exposed to the air. M. Proust, to whom we owe these discoveries, thinks the division of a carbonaceous residue, by an earth or a metallic oxide, to be the only condition necessary to the production of a pyrophorus.

The acid of vinegar forms, with ammoniac, a liquor that is called *spirit of Mendererus*, and is properly ammoniacal acetite. This salt is so volatile that it cannot be evaporated without a great part of it being lost; yet, by slow evaporation, it may be obtained in needled crystals, which are of a hot pungent taste, and very speedily attract

attract moisture from the atmosphere. Ammoniacal acetite is decomposed by the action of fire ; by lime and alkalis, which disengage the ammoniac ; and by mineral acids, which separate the acetous acids.

Vinegar acts upon almost all metallic substances ; and exhibits, in its combinations with them, a number of very important phenomena.

It does not appear that this fluid is capable of effecting an immediate solution of oxide of arsenic ; but this oxide, by distillation with equal parts of acetite of potash, afforded M. Cadet, and the chemists of the Academy of Dijon, a fuming liquor of a very stinking smell, very tenacious, and of a very singular nature. M. Cadet first observed this liquor to be capable of inflaming fat lute. The academicians of Dijon, wishing to examine a yellowish matter of an oleaginous consistency, which they found accumulated in the bottom of a bottle containing arsenico-acetous fuming liquor, decanted off a part of the supernatant liquor, and poured the rest on a paper-filter. Only two or three drops had passed, when suddenly there arose a very thick smoke, of a nauseous smell, which formed a column extending from the vessel to the ceiling of the room : a sort of ebullition took place around the edges of the matter, and from it there arose a beautiful rose-coloured flame, which continued to burn for several seconds. A particular account of these elegant experiments may be seen in the third volume of the *Elements of Chemistry* of Dijon. These chemists compare the liquor of which we are speaking to a liquid phosphorus : We take it to be a sort of pyrophorus, as well as some others of which we are hereafter to speak. The residue remaining after the distillation of
acetite

acetite of potash, with oxide of arsenic, consists chiefly of potash.

Vinegar dissolves oxide of cobalt : the solution is of a pale rose-colour.

It acts neither on bismuth, nor on its oxide ; but dissolves oxide of manganese.

It accomplishes a direct solution of nickel, according to M. Arwidsson. This solution affords green crystals, of the form of a spatula.

This acid does not act upon antimony ; but it appears to dissolve the vitreous oxide of that semi-metal ; for Angelus Sala made up an emetic preparation of these two substances.

Both zinc and its oxide dissolve very readily in distilled vinegar. M. Monnet obtained, by evaporating this solution, crystals in the form of broad plates. Acetite of zinc fulminates on the coals, and gives out, on the occasion, a faint bluish flame. It affords, by distillation, an inflammable liquor, a yellowish oily fluid, the colour of which soon changes to a deep green, and a white sublimate, which burns by the light of a taper, with a beautiful blue flame. The residue is in the state of a scarcely combustible pyrophorus.

The acid of vinegar does not dissolve mercury in a metallic state. This combination may, however, be effected by attenuating the mercury into very small particles in the manner of Keyser. Mercury, in the state of oxide, combines easily with vinegar. The only thing necessary to produce this combination, is, to boil the acid upon the red oxide of mercury, called *precipitate per se*, upon *turbith*, or upon mercury, precipitated by potash from a nitric solution of that metal. The liquor be-
comes

comes white, but regains its transparency while boiling. It is filtrated. By cooling it precipitates silver-coloured crystals, in the form of sparkling scales, resembling the crystals of the boracic acid. This acetite of mercury has obtained the name of *mercurial foliated earth*. It is prepared in an instant, by pouring a nitric solution of mercury into a solution of acetite of potash. The nitric acid combines with the fixed alkali of the latter of these salts, and forms with it nitre, which remains dissolved in the liquor; and the oxide of mercury, combining with the acid of vinegar, is precipitated in brilliant scales. This mixture is filtrated; and the acetite of mercury then remains on the filter. This salt is decomposed by the action of fire. Its residue affords a sort of pyrophorous. It is easily altered by combustible vapours.

Tin suffers but very little alteration from vinegar. This acid dissolves only a very small portion of the metal. The solution afforded M. Monnet, by evaporation, a yellowish substance resembling gum, and of a foetid smell.

Lead is one of those metals on which the acid of vinegar acts with the most powerful energy. It dissolves this metal with the greatest facility. Plates of lead, exposed to the steam arising from hot vinegar, are covered over with a white dust, which is called *ceruse*, and is nothing but oxide of lead, with a little vinegar. This oxide, ground with one-third part of chalk, forms what is used in painting under the name of white lead. To saturate vinegar with lead, the acid is poured upon *ceruse* in a matrafs. This mixture is digested on a sand-bath. After remaining in digestion for several hours, the

the liquor is filtered and evaporated to a pellicle. It affords, by cooling and rest, white crystals,—in the shape of irregular needles, if the liquor was too much concentrated,—or of flat parallelipeds, terminating in two sloping surfaces, when the process of evaporation is properly conducted. This acetite of lead is called *sal* or *faccharum Saturni*, on account of its saccharine taste. Its taste is likewise stiptic. A similar salt is prepared of litharge and vinegar. Equal parts of the two substances are boiled together till they be mutually saturated; and this mixture, after being evaporated to the consistency of clear syrup, forms M. Goulard's *extract of Saturn*, which was known long before his time by the name of *vinegar of Saturn*. Acetite of lead is decomposed by heat. It affords an acid liquor, which is ruddy, and strongly foetid, but very different from radical vinegar, or the pure acetic acid of which we are soon to speak. The residue is a very good pyrophorus. This salt is decomposed by distilled water, by lime, alkalis, and mineral acids. The *extract of Saturn*, diluted in water, and mixed with a little brandy, forms the *vegeto-mineral water*.

Vinegar dissolves iron with considerable energy. The effervescence which takes place in this solution is owing to the disengagement of hydrogenous gas from the water which appears to be decomposed. The liquor assumes a red or brown colour. By evaporation, it affords nothing but a gelatinous magma, mixed with a few oblong brown crystals. Acetite of iron has a stiptic sweetish taste. It is decomposed and deprived of its acid by fire. It attracts moisture from the atmosphere, and is decomposed in distilled water. When heated till it ceases to
exhale

exhale the smell of vinegar, it then leaves a yellowish oxide, subject to the attraction of the loadstone. The acetous solution of iron, affords with nut-gall a very black ink, and might be very advantageously employed in dyeing. Alkaline Prussiates precipitate from it a very bright Prussian blue. Black, yellow, and brown oxide of iron, and native carbonate of iron, or *spathose iron-ore*, afford with vinegar solutions of a very beautiful red colour.

Copper is very easily dissolved in the acetous acid. This solution, with the help of heat, takes by degrees a green colour. But the acid acts more readily on this metal, when it has been already oxidated by vinegar, and so converted into the substance called *verdigris*. Verdigris is prepared in the neighbourhood of Montpellier, by laying plates of copper into earthen vessels, in layers covered with the husks of grapes, previously sprinkled and fermented with weak vinegar. The surfaces of these plates are soon covered with a green rust; which is increased by piling them upon each other, and sprinkling them with weak vinegar. The copper is then scraped, and the verdigris put up in leather-bags for sale. M. Montet, an apothecary at Montpellier, has given a very good description of this process in two Memoirs, printed among the Memoirs of the Academy of Sciences, in the years 1750 and 1753. Verdigris readily dissolves in vinegar. This solution is of a beautiful green colour, and affords, by evaporation and cooling, green crystals in truncated quadrangular pyramids, which are called *crystals of Venus*. The crystals prepared for commerce, which are called *distilled verdigris*, on account of their being prepared
with

with distilled vinegar, are in the form of fine pyramids. These crystals take a pyramidal form, from their being deposited on a piece of wood split into four branches, which are kept separate by a piece of cork.

Acetite of copper has a very strong taste, and is a violent poison. It is decomposed by the action of fire. It effervesces in the air, and is covered over with a dust, the colour of which is a much paler green than the colour of the original salt. It is entirely dissolved in water, but not decomposed. Lime-water and alkalis precipitate this solution.

When this salt is reduced to powder, and distilled in a glass or earthen retort, with a receiver, it affords a fluid, which is at first white and somewhat acid, but soon becomes so strong as to be not inferior in acidity to concentrated mineral acids. The receiver is changed, in order that the phlegm and the acid may be obtained separate. The acid has been called *radical vinegar*, or *vinegar of Venus*. It is of a green colour, which it owes to a certain quantity of calx of copper that is carried up with it in the distillation. When the distillation ceases, and the retort is red-hot, the residue remaining is a brown copper-coloured dust, which frequently communicates a metallic tinge to the sides of the vessel. This residue, as has been observed by the Duke d'Ayen, and M. Proust, is strongly pyrophoric. *Vinegar of Venus* is rectified by distillation with a moderate heat. It is then perfectly white, provided it be not too much urged with fire towards the end of the operation, so as to reduce the oxide of copper, remaining in the retort, to too dry a state. The reduction of copper
which

which may be observed in this operation, contributes to explain the nature of *radical vinegar*. This acid appears to bear the same relation to common vinegar which the oxygenated muriatic acid bears to the pure muriatic acid ;—or rather, the same which the sulphuric bears to the sulphureous acid, or the nitric to the nitrous acid. In this operation, the acetous acid combines with the oxigene of the oxide of copper, which passes at the same time into a metallic state. The effects, in the production of which *radical vinegar* differs essentially from common vinegar, seem to be owing to the oxigene which that acid acquires. For this reason, we give it, according to the rules of the Nomenclature now adopted through this work, the name of the *acetic acid*.

The acetic acid, or radical vinegar, rectified in this manner, is of so lively and pungent a smell, that it can scarce be borne. Such is its causticity, that when applied to the skin it corrodes and cauterizes it: it is extremely volatile and inflammable: when heated in contact with air, it takes fire, and burns with more or less rapidity, according as it is more or less rectified. This fact has led chemists to think, that vinegar contains alcohol, and is a sort of natural æther. The poignant agreeable smell which the first portions of this acid diffuse, favours the same opinion.

Acetic acid evaporates all away in the air. It combines with water, with a considerable heat: with earths, alkalis, and minerals, it forms salts different from those into which common vinegar enters; we call them *acetates* of potash, soda, zinc, mercury, &c. M. de Laffone has shewn, that the ammoniacal salt formed by radical

vinegar, or the acetic acid, is not of the same nature with ammoniacal acetite, or spirit of Mendererus. Although we are not yet sufficiently acquainted with all these acetates; yet their form, taste, and solubility, shew plainly, that they are of a different nature from acetites.

The Marquis de Courtanvaux has shown, that nothing but the last portion of the acetic acid, obtained by the distillation of acetite of copper or *verdigris*, is susceptible of inflammation, and that it possesses likewise the property of being liable to congelation by cold. This last portion, rectified, crystallized in the receiver, in large plates, and in needles; nor did it become fluid, till it was exposed to a heat thirteen or fourteen degrees above the freezing point. In this property, this substance resembles oxygenated muriatic acid.

The acetic acid decomposes alcohol, and forms æther, as readily as mineral acids, as has been discovered by the Count de Lauraguais. All that is necessary to produce this effect, is to pour a quantity of radical vinegar upon an equal quantity of alcohol. A considerable heat is excited. The retort is placed upon a hot sand-bath; and two receivers are adapted to it, the most distant of which is immersed in cold water or pounded ice. This mixture must be quickly boiled. There arises from it, first, a dephlegmated alcohol; after that, æther; and then an acid, which becomes gradually stronger, as the process advances. In the retort there remains a brown mass, much like a resin. Care must be taken to change the receiver as soon as the smell of the æther becomes acrid and pungent, and to collect the acid by itself. The acetic æther, thus obtained, must be rectified by a moderate

moderate heat with potash. In this operation there is a good deal of it lost. The formation of this æther is owing to radical vinegar's containing an excess of oxygen. Scheele relates, that he never succeeded in preparing acetic æther from radical vinegar combined with alcohol, and could not accomplish this preparation without adding a mineral acid. M. Pærner had already made the same remark on the difficulty of obtaining acetic æther by M. de Lauraguais's process. A great many French chemists have, however, employed this process, and I myself, among others, with sufficient success.

M. de La Planche, apothecary, prepares acetic æther by pouring concentrated sulphuric acid and alcohol upon acetite of lead introduced into a retort. The theory and practice of this operation differ in no respect from those of the analogous process by which nitric and muriatic æther are prepared. Acetic æther has, like every other sort of æther, an agreeable smell, which, however, is always mixed with the smell of vinegar, though not acid. It is very volatile and inflammable, burns with a lively flame, and leaves, after its combustion, a carbonaceous mark.

Chemists need to make yet many more researches into the nature of the acetic acid. What we have here said concerning its properties, will serve to shew, 1. That it differs in a singular manner from the acetous acid, or common vinegar. 2. That the difference is owing to the acetic acid's containing more oxygen than the acetous; which excess it has derived from the oxide of copper.—Let us now resume the examination of the other properties of common vinegar.

The acetous acid, with the help of heat, dissolves the gold precipitated by fixed alkali, from the oxygenated muriatic acid. This acetous solution of gold, precipitated by ammoniac, affords *fulminating gold*, as has been shown by Bergman. It acts in the same way on platina and silver. While these metals are in a metallic state, vinegar is incapable of acting upon them; but it dissolves them, when exposed to it in the state of oxides.

Vinegar is capable of combining with many of the immediate principles of vegetables: It dissolves extracts, mucilages, and essential salts. It combines with the aroma: It is thought to be the proper solvent for gum resins. It has even, at length, or by the way of distillation, a discernible influence on fat oils, and reduces them to a sort of saponaceous state. The combinations of vinegar with vegetable substances have not been farther examined with any accuracy.

This acid is used in the extraction of several of the principles of vegetables, especially in the extraction of their odoriferous principle; and various sorts of vinegar, both simple and compound, are prepared for medical uses. Vinegar of squills, colchicum, &c. afford instances of the simple; theriacal vinegar, and the vinegar of the four thieves, are compounds. These medicines are prepared by maceration and digestion, continued for several days. As this acid is volatile, it is distilled on aromatic plants, whose odoriferous principle it takes up. Of this kind is the distilled vinegar of lavender, which is used at the toilet. These liquors are, in general, not so agreeable as spirituous distilled waters.

Vinegar is very much used as an article of seasoning. It is much used in medicine, as being cooling and anti-septic.

septic : There is a syrup made up of sugar and vinegar, which is administered with success in burning and putrid fevers, &c. This acid, applied externally, is astringent and resolvent. All its combinations are, in like manner, used as excellent medicines.

Acetite of potash, and acetite of soda, which are known by the names of *terra foliata tartari*, and *acetous mineral salt*, are powerfully discutient and aperient : They are given in doses of half a drachm, or even a drachm each.

Spirit of Mendererus, or ammoniacal acetite, given in doses of a few drops, in certain drinks, is aperient, diuretic, cordial, antiseptic, &c. It is often successful in the leucophlegmatia, or swelling of the external parts of the body.

Acetite of mercury, or *terra foliata tartari*, is an excellent anti-venereal : it is the principal ingredient in Keyser's pills.

The *extract of Saturn*, *vinegar of Saturn*, and *vegeto-mineral water*, are applied externally, as desiccatives. They are violently repercussive, and ought therefore to be very cautiously administered, especially when applied to excoriated or ulcerated parts. Boerhaave mentions several young women who were attacked with consumptions, in consequence of the external use of preparations of lead.

Ceruse enters into the composition of desiccative unguents and plasters ; and *verdigris* into several collyria and unguents.

The acetic acid, or *radical vinegar*, is given as a very active, irritating, and stimulating medicine. It is held

to the nostrils of persons in fainting-fits. In order that it may be the more conveniently made use of, a certain quantity of this acid is poured on sulphate of potash in a coarse powder, and put into a close-stopped phial. This medicine is well known in the world, under the name of *salt of vinegar*.

Acetic æther has not yet been applied to use ; and it is not known whether it possesses any virtues different from those of the other sorts of æther.

C H A P. XXV.

Of the Putrid Fermentation of Vegetables.

ALL vegetable substances that have suffered the spirituous and the acid fermentation, are still liable to undergo another intestine motion, which is called *putrid fermentation*. Stahl and several other chemists think this fermentation to be nothing but a consequential part of the two other fermentations already described;—or rather, that the phænomena of all the three arise from *one* internal emotion, the tendency of which is to destroy the texture of the solids, and to alter the nature of the fluids. It is in fact observable, that certain vegetable substances pass, of themselves, through three successive fermentations. For instance, all saccharine matters, diluted in a certain quantity of water, and exposed to a heat of—from 60 to 80 degrees, afford, first wine, then vinegar, and at last lose entirely their character of acidity: they are altered, become putrid, lose all their volatile principles, and are in the end re-

duced to a dry, insipid, earthy substance. It is to be observed, however, that a great number of vegetable substances are not, in any sensible manner, liable to pass successively through these three sorts of fermentation, in the above-mentioned order. Insipid mucilages and gums dissolved in water pass into an acid, without becoming discernibly spirituous: the glutinous matter again seems to pass, all at once, into a state of putrefaction, without becoming acid. It appears, then, that although in several of the principles of vegetables, these three fermentations follow each other in regular succession, yet many of those principles are susceptible of the two latter species of fermentation, without having previously undergone the former; nay, are even liable to putrefaction, without becoming previously acid. Those of the last mentioned character partake of the nature of animal substances, and accordingly afford ammoniac by the action of fire, and azotic gas by the acid of nitre. It is in consequence of their possessing such characteristics, that these vegeto-animal substances putrefy so readily.

Certain conditions, well worthy of our attention, are requisite, in order that the intestine motion which changes the nature of vegetable matters, and reduced them to their elementary principles, may take place. Humidity, or the presence of water, is one of the most indispensable of these conditions. Dry solid vegetables, such as wood, suffer no alteration while they continue in that state; but if they be moistened, and their fibres separated, an intestine motion then commences. Water appears, therefore, to be one of the causes of putrefaction. When we come to examine the animal kingdom, we will have occasion to see, that the intestine motion

with

with which putrefaction begins is owing to the decomposition of that liquid. Heat is not less necessary to putrefaction. Cold, or the temperature of ice, is not only adverse to this spontaneous destruction in substances which have not yet begun to suffer from it, but even retards its progress, and, in some measure, reverses it where it has already begun to operate. The degree of heat necessary to putrefaction, is much inferior to what is required for the spirituous and the acid fermentation; for putrefaction takes place at the temperature of 45 degrees; but a more considerable heat is still more favourable; at least, if it be not so violent as to volatilize all the moisture of the putrescent substance, and render it entirely dry. Access of air is another condition, singularly favourable to putrefaction; for vegetable substances are very well preserved *in vacuo*. The contact of air, however, is not so indispensably necessary to putrefaction as the two other conditions already mentioned; for this phenomenon sometimes takes place without its assistance.

The putrefaction of vegetables exhibits peculiar phenomena. Vegetable fluids, when they putrefy, become turbid, lose their colour, and deposit various sediments: bubbles ascend to the surface, and mouldiness gathers over it in the beginning of the alteration. Soft vegetable matters exhibit the same phenomena, on being simply wet. The emotion then produced is at no time so considerable as that which appears in the cases of spirituous and acetous fermentation. The putrefying body does not appear to increase in bulk, nor does its temperature become higher. But the principal phenomenon of putrefaction is, change of smell, with the volatilization

of an urinous, pungent, acrid principle,—in a word, ammoniac. From this circumstance, putrefaction has been called *alkaline fermentation*, and ammoniac considered as its product. The pungent smell exhales by degrees, and is succeeded by a nauseous insipid smell, which can scarce be described. The decomposition has now attained its height: The putrid vegetable mass is become very soft, like a jelly; it sinks down, and the odorous principle exhaling from it suffers a great many successive modifications. At last it becomes dry, and loses, by degrees, its disagreeable smell; and what remains is nothing but a blackish, and seemingly carbonaceous residue, known by the name of *humus vegetabilis*, which is found to contain nothing but saline and earthy substances. Such is the order of the phenomena that are successively observed in the spontaneous decomposition of putrefying vegetables. But this process of decomposition, when carried so far as to reduce the vegetable body to an earthy or saline residue, is extremely tedious, and, we may even add, has never yet been observed by any person with suitable attention. Chemists and naturalists have paid still less attention to the putrefaction of vegetable, than to that of animal substances. No philosopher has hitherto undertaken to observe all the phenomena of the putrefaction of vegetables, but many have begun to describe those which attend the putrefaction of animal matters. Here, therefore, it appears proper for us to conclude our history of the spontaneous and natural decomposition of vegetables with the following observations: 1. The little which we have here said concerning it is sufficient to show, that the putrefaction of vegetables attenuates, volatilizes, and de-

stroy all their humours, and reduces them to an earthy state : 2. We have as yet no certain knowledge of the phænomena and the limits of this species of putrefaction, which is to be carefully distinguished from the putrefaction of animal matters : 3. Lastly, As this fermentation is much more conspicuous, and has been much more attentively observed in the humours and solids of animals; the more extensive detail of particulars which we are to give, in our account of animal substances, will complete the sketch which we have here marked out, and conclude the history of those facts that are known concerning putrefaction.

P A R T

PART FOURTH.

THE ANIMAL KINGDOM.

CHAP. I.

Of the Chemical Analysis of Animal Substances in general (1).

IN the analysis of animal substances, we meet with greater difficulties than in any other part of chemistry; and our chemical knowledge of those substances is accordingly in a more imperfect state than any other branch of the science. The ancient chemists were content with distilling them by naked fire; an operation which is at present known to alter and totally destroy the nature of such compound bodies as the solids or fluids of animals. The only parts of animals that have yet

(1) In the second edition of this Work, the animal kingdom began with a brief account of the nature of animals, the distinctions subsisting among them, the methods requisite for marking out those distinctions in Natural History, and the Natural Philosophy of Animals. The mode of arrangement now adopted in these volumes, and the little connection between the natural description of animals, and the chemistry of animal matters, have induced me to remove that part into a fifth volume. A.

yet been subjected to an analysis, are some of the humours of the human body, and the humours of certain quadrupeds.

Many circumstances have concurred to retard the progress of this branch of chemistry. The difficulty and disagreeableness attending researches of this kind ; the imperfection of the chemical methods with which, till within these few years, animal matters were always treated, and which constantly produced on them great alterations ; the impossibility which was always found of approaching near to a reproduction of any animal matter by synthesis ; and, above all, the smallness of the inducements which any but medical chemists could have to engage in such researches ; are the principal reasons which have prevented the enlargement of this department of the science of chemistry. But the researches of several moderns, especially of Messrs Rouelle, Macquer, Bucquet, Poulletier de la Salle, Berthollet, Proust, Scheele, and Bergman, have here opened a new tract of discovery, and shew, that the art of healing may derive the most signal advantages from researches of this kind.

The human body, and the bodies of quadrupeds—the principal animals which engage our attention—are composed of fluids and solids. The humours of animals are divided into three classes, according to the purposes for which they serve. The first contains the recremental humours, the use of which is to nourish certain organs: the second comprehends excrementitious humours, which are evacuated by certain excretories, as useless, and even noxious, when retained too long within the body: the third class consists of humours to which the

1

characteristics

characteristics of both the two former classes belong, they being partly recrementitial, and partly excrementitial. To the first class belong the blood, the lymph, the jelly or gelatinous part, the fibrous or glutinous part, the fat, the marrow, the matter which supports interior perspiration, and the osseous juice. The second class consists of the fluid which is insensibly transpired by the pores, the sweat, the mucus of the nostrils, the cerumen of the ears, the gummy matter of the eyes, the urine, and the fæces. Those of the third class are, the saliva, the tears, the bile, the pancreatic juice, the gastric and intestinal juices, the milk, and the feminal liquor. We cannot examine all these fluids in the order in which they are here mentioned : 1. Because they are still but very little known ; 2. Because it is absolutely necessary that we treat first of such as have been the most completely analysed.

The solids of animals, which form the parenchyma of their different organs, may be divided into three classes. In the first of these classes I rank the soft white parts, such as the laminæ of the cellular tissue, the membranes, the membranous viscera, the aponeuroses, the ligaments, the tendons, and the skin. The soft red parts form a second class, very different from the former ; such are, particularly, the muscles, and a part of the organs which contain muscular fibres, as the stomach, the intestines, the bladder, the matrix, &c. Lastly, the third class comprehends the osseous or bony solids.

Animal matters are at present analysed in a very different way from that in which they were analysed a few years since. They are no longer subjected to decomposition by fire ; they are now treated by re-agents, particularly

particularly acids, alkalis, alcohol, &c. The different fluids intermingled with each other, or contained in the vesicles of the different parts, are separated by rest, decantation, filtration, or expression. The action of these substances on colouring matters is examined, and the several changes which they are liable to suffer in different temperatures are observed. Animal liquors are carefully evaporated, and the different salts which they contain extracted from them unaltered.

By these methods of analysis, modern chemists have made a number of important discoveries concerning animal substances. Scheele has found them to contain several acids different from those which were before known. M. Berthollet has demonstrated the existence of phosphoric acid, in a naked state, in urine and sweat; and has likewise found, in animal matters, a remarkable quantity of the azotic principle. This last discovery is one of the most important facts which the analysis of animal matters has made known to us. The existence of azote in these substances, especially in their fibrous parts, accounts for the difference between animal and vegetable matters. This body is obtained in the state of elastic fluidity, or in azotic gas, by treating the flesh of the muscles with nitric acid: even without the operation of any external heat, it is disengaged in a pretty large proportion: it passes before the nitrous gas; and when the nitrous gas begins to be disengaged, the operation should be stopped, and the vessels changed.

M. Berthollet explains by this discovery the formation of the ammoniac which animal substances afford, when treated with fire,—the production and disengage-

ment of this salt by putrefaction,—and the relation between these substances and vegetable matters that are liable to putrefaction, and afford ammoniac by distillation. It appears, in fact, that in both these instances, the ammoniac is formed by the combination of hydrogen with azote. I believe I cannot here do better than give, in M. Berthollet's own words, what he has said concerning the nature of animal substances in general, in a Memoir read before the Faculty of Medicine, and inserted in the *Journal de Physique*, vol. 28. page 272.

“ Organized bodies are chiefly composed of two substances, which are distinguished from each other by very eminent peculiar characteristics. Of these substances, one class affords acids, when decomposed by the action of fire; the other *volatile alkali*: The one class forms *ardent spirit* by fermentation; the other immediately putrefies, still affording *volatile alkali*: The one leaves, when calcined, a coal that burns easily; the other is reduced to a coal which burns with difficulty: The one, in short, forms the greater part of vegetable, the other of animal substances; and hence they are distinguished by these two different denominations.

“ M. Bergman, by means of sugar and the *nitrous acid*, produced an acid which he called the *saccharine acid*, possessing peculiar and remarkable properties. On applying to animal substances this analysis by *nitrous acid*, I found that they all afforded more or less *saccharine acid*, which was always accompanied with a peculiar oil. I observed that no ammoniacal salt was obtained, but a residue remained, which vegetable substances do

“ not

“ not afford. From these first experiments, I concluded,
“ in the *Memoirs of the Academy for the year 1780*, that
“ animal matters contained some substance analogous to
“ sugar, in combination with an oil which I considered
“ as peculiar to animal matters. I learned farther from
“ my experiments, that *volatile alkali* did not exist in
“ animal substances, but was produced by some combination, effected either by the action of heat, or by
“ the influence of putrefaction. And lastly, The residue,
“ concerning which I did not explain my sentiments in
“ that Memoir, contains an excess of phosphoric acid,
“ combined with calcareous earth.

“ I afterwards examined the action of metallic *calces*
“ and salts on animal substances, and proved, that the
“ action to which these owed their causticity was a consequence of the chemical affinities by which metallic
“ *calces* tended, with more or less force, to revivication ;
“ the *calces* of silver and mercury, which are very easily
“ reduced, having an high degree of causticity, and
“ forming very caustic salts. It follows, on applying
“ the late discoveries of natural philosophers to the theory which I have given, that it is the air, existing in a
“ combined state in metallic *calces*, and without its principle of elasticity, which tends to unite with some
“ principle in animal substances ; which principle appears to me to be the oil which they contain. But
“ the causticity of alkalis cannot be ascribed to the same cause : it must be owing to some other affinity.
“ In the *Memoirs of the Academy for the year 1782*, I have proved that caustic alkali dissolves
“ animal substances, without dividing their principles.
“ I have explained the properties of this combination,
and

“ and afterwards employed it in uniting animal substances with the different metallic *calces*. Several combinations, not previously known to chemists, were produced: But caustic alkali, treated in the same way with vegetable substances, formed no combination with them.

“ Pursuing my researches, I have at length discovered the principles of *volatile alkali*. I have shown *volatile alkali* to be a combination of detonating *inflammable gas*, or, more accurately, of the inflammable gas of water with *phlogisticated* or *mephitic* air, in such proportions, that inflammable gas composes one sixth of the weight, or two thirds of the bulk of *volatile alkali*. I next ascertained in what manner *volatile alkali* may be produced by putrefaction, or the action of fire. All substances possessing the characteristics of animal substances contain *mephitic*, which may be separated from them in abundance, by the operation of the *nitrous acid*. When those substances are distilled, therefore, their *mephitic* must of necessity either pass into some new combination, or be found among their aeriform products. But among these last it is never found; as I fully ascertained by detonizing *inflammable gas*, obtained by this means, in M. Volta's eudiometer, and comparing it with inflammable gas obtained by distillation from charcoal, and with that of vegetable substances; and, after the *inflammable gas*, there is none other but the *volatile alkali* among the products obtained by distillation from animal substances, into the composition of which the *mephitic* can possibly be received. Consequently, whenever *volatile alkali* is formed, the *mephitic* of the animal substances combines

“ combines with the *inflammable gas* separated from the
 “ oil, or more probably with that produced by the de-
 “ composition of the water, whose vital air combines
 “ at the same time with charcoal, to form *fixed air*;
 “ in putrefaction, the *inflammable gas* combines with the
 “ *mephitic*; whereas, in the spirituous fermentation, the
 “ same gas combines with a vegetable oil and sugar to
 “ form *spirit of wine*, in which I have discovered and
 “ separated these substances by means of the *dephlogisti-*
 “ *cated marine acid*.

“ From these several observations, it follows, that
 “ animal substances are of a much more compound na-
 “ ture than substances purely vegetable. They contain
 “ a matter analogous to sugar, a peculiar oil, phospho-
 “ ric acid combined with calcareous earth, *mephitic*, and
 “ very probably *fixed air*. It is the phosphoric acid
 “ which exists in the coal of animal substances, in com-
 “ bination with a portion of real charcoal, oil, and earth,
 “ that appears to me to occasion the difference observed
 “ between the coals of animal and those of vegetable
 “ substances.”

Such is the accuracy and perspicuity with which M.
 Berthollet explains the nature of animal substances in
 general. When these distinct facts and fair deductions
 are compared with the vague notions which before pre-
 vailed concerning the difference between animal and
 vegetable matters, the progress which chemistry has
 made within these few years, by means of the researches
 of Swedish and French chemists, cannot but appear
 astonishing. There is the strongest reason to hope, that
 farther experiments on animal matters, upon the same

plan which has been marked out and pursued by the most celebrated chemists, from Margraff and Rouelle to the present instant, will supply a great deal of valuable information concerning these substances ; their formation, the alterations which they are liable to undergo, and their destruction ; and particularly, may be of the most essential service to the science of Medicine. The truth of this assertion will be fully proved, by the account of the discoveries already made, and of their application, which we are to exhibit in the following chapters.

C H A P.

C H A P. II.

Of the Blood.

THE most important, the most compound, and the most impenetrable of the recrementitial humours, is the blood. We treat of it first, because the greatest physicians maintain it to be the source and centre of all the other animal fluids. Many physicians, especially M. Bordeu, have considered it as a sort of fluid flesh, a compound of all the animal humours : an opinion, which, though highly probable, has not been yet fully demonstrated.

The blood is a fluid of a beautiful red colour, of a fat, unctuous, and, as it were, a saponaceous consistency ; of a taste somewhat saline, but almost insipid ; and contained in the heart, arteries, and veins. This fluid is differently modified by the different parts through which it flows : For instance, in the arteries and veins, in the breast, and the region of the liver, in the muscles and the glands, &c. it is not the same. This fact has not sufficiently engaged the attention of ch

In considering the blood as it exists through the whole animal kingdom, we observe, that in different animals it is singularly diversified in colour, consistency, smell, and especially temperature. The last is the most important of all these properties, and seems to depend on the circulation and the respiration. The human blood, and that of quadrupeds and birds, is hotter than the medium which they inhabit; and, for this reason, these are called *hot-blooded animals*. The blood of fishes and reptiles, again, is nearly of the same temperature with the medium which they inhabit; and these are, for this reason, called *cold-blooded animals*. Other properties of this fluid, especially its chemical qualities or characteristics, would probably be found, if we were acquainted with the blood of all animals, to be subject to the same variations.

The human blood, which more especially engages our attention, is differently modified by the age, the sex, the temperament, and the state of the health, of each individual. In infants, the female sex, and phlegmatic persons, it is paler and thinner. In robust and healthy persons, it is thick, of a deep red colour, almost black, and of a much more saline taste than in the former.

Before proceeding to an analysis of the blood, it is necessary that we get acquainted with its physical properties—its colour, heat, taste, smell, and peculiar consistency—of which we have already taken notice. By the microscope we discover in it a great many globules, which, according to Lieuwenhoek and Boerhaave, when broken in circulating through the smaller passages, lose their red colour, and become first yellow, and then white; so that, according to the physician of Leyden,

a red globule is an assemblage of other smaller white globules, and owes its colour to its aggregation. There is another singular property belonging to the blood. While hot and in motion, it continues fluid and red : When cooled and at rest, it becomes a solid mass, which, by degrees, separates into two parts ; the one red and supernatant, its colour dark, and its consistency concrete, till such time as it suffer an alteration ;—this is called the *clot of the blood* : the other occupies the bottom of the vessel, and is of a greenish yellow colour, and adhesive ;—it is called the serum or lymph. This spontaneous coagulation and separation of the two parts of the blood takes place in the last moments of an animal's life ; and produces those concrete matters which are found in the heart, and the larger vessels of deceased animals, and have been mistaken for polypi.

Blood, exposed to a gentle and continued heat, passes into the state of putrid fermentation. When distilled on a water-bath, it affords a phlegm of a faint smell, which is neither acid nor alkaline, but easily putrefies, in consequence of its containing an animal substance dissolved through it. Exposed to a more intense heat, blood, as has been discovered by De Haen, gradually coagulates and becomes dry : it then loses seven-eighths of its weight, and becomes capable of effervescence with acids. By conducting the fire properly, it may be hardened into a sort of corneous substance. Desiccated blood, exposed to the open air, attracts from it some degree of moisture, and, in the course of a few months, there is formed on it a saline efflorescence, which Rouelle has determined to be carbonate of soda. When distilled by naked fire, it affords a saline phlegm,—that is, a

phlegm holding in solution an ammoniacal salt, super-saturated with ammoniac. The nature of the empyreumatic acid contained in this ammoniacal salt, which was first observed by Wiewfens, and has given rise to so many disputes among physiologists, has never yet been sufficiently examined. After this phlegm, a light oil passes, —then a ponderous coloured oil, and ammoniacal carbonate contaminated with a thick oil. There remains in the retort a spongy coal, very difficult to be incinerated, which is found to contain muriate of soda, carbonate of soda, oxide of iron, and a matter apparently earthy, which seems to be calcareous phosphate.

Blood, when burnt in a crucible, affords several products, in the following order. 1. Water and a little ammoniac: 2. Oil and carbonate of ammoniac, which forms a yellowish vapour, thicker than the former: 3. Prussic acid, which is easily distinguished by its foetid smell of peach-flowers: 4. Phosphoric acid, which is formed by the combustion of phosphorus, and is not disengaged till the blood be reduced to a coal: 5. Carbonate of soda, which is volatilized at an intense heat: 6. After this there remains in the crucible only a blackish, granulated, crystallized oxide of iron, mixed with calcareous phosphate.

Blood combined with alkalis, without previous decomposition, becomes more fluid by standing. Acids instantaneously coagulate it, and alter its colour. By filtrating this substance, evaporating the liquor passed through the filter, drying it before a moderate fire, and lixiviating the matter that has been dried, neutral salts are obtained, consisting of soda, with the acid that was mixed with the blood. Alcohol coagulates blood.

If entire blood, mixed with a fourth part of its weight of water, be coagulated by heat, and if a part of the fluid that swims above the coagulated portion be evaporated, a substance of a brown yellow is obtained, which is easily distinguished to be true bile. This discovery, which was made in 1790, confirms the opinion of the ancients; who considered bile as a constituent part of blood.

Experiments made on blood in its original state, do not discover the nature of the substances of which it consists. But the spontaneous decomposition of blood, and the separation of its two component parts, the clot and the serum, afford us an opportunity of acquiring that knowledge by examining each of these matters by itself. Till within these few years, the chemical analysis of the blood was confined to what has been related in the foregoing pages; but Messrs Menghini, Rouelle the younger, and Bucquet, have examined this fluid in a very different manner. The two last of these chemists especially have conducted their experiments on this matter in a way which shews to what perfection the analysis of animal matters may be carried, by proceeding on their plan. The following account of the properties of the several substances which compose the blood, is derived from the discoveries of those philosophers, and from those which I have made myself.

The serum is very far from being pure water, but a peculiar matter, highly worthy of examination; to which we give the name of the *albuminous fluid*. It is of a yellowish white colour, somewhat inclining to green; its taste is saltish, but nearly insipid; its consistency unctuous and adhesive. When exposed to the action of fire, it coagulates and becomes hard, long before it can be

heated to ebullition : it communicates a green tinge to syrup of violets. By distillation on a water-bath, it affords a phlegm of a mild insipid taste, which is neither acid nor alkaline, but speedily putrefies. After losing this phlegm, it is dry, hard, and transparent like horn : it is no longer soluble in water : by distillation in a retort, it affords an alkaline phlegm, a considerable quantity of ammoniacal carbonate, and a very foetid thick oil. All these products, in general, have a peculiar foetid smell. The coal of the serum, when distilled by naked fire, almost entirely fills the retort. It is so difficult to incinerate, that it must be kept burning for several hours, and exposed to a great deal of fresh air, before it can be reduced to ashes. The ashes are of a blackish grey colour, and contain muriate and carbonate of soda, with calcareous phosphate.

The serum, if exposed for some time to an hot temperature, in an open vessel, passes readily into a state of putrefaction, and then affords a considerable quantity of ammoniacal carbonate, with an oil, the smell of which is insufferably nauseous. It putrefies so speedily, that Bucquet could not discover whether it passed into an acid state before becoming alkaline. This liquor combines with water in any proportion ; and then it loses its consistency, its taste, and its greenish colour. To promote the combination, the mixture needs to be shaken ; because the difference between the densities of the two fluids obstructs their union. The serum, when poured into boiling water, coagulates, almost wholly, instantaneously. A portion of this fluid forms, with the water, a sort of opaque and milky white liquor ; which, according to Bucquet, possesses all the characteristic properties

of milk ; that is, it is rarefied, and caused to mount up, like that fluid, by heat, and is coagulated by the same agents—by acids, and by alcohol.

The serum or albuminous fluid possesses the property of fixing and rendering solid by heat, two or three times its weight of water. When seven or eight parts of water are added to one of serum, then the albumen is not coagulated by heat. The cause of this singular property, of coagulating by heat, which the serum of the blood possesses, has hitherto eluded the researches of philosophers. I imagine it to be owing to the combination of oxigene, assisted by heat, as it is in all other substances ; since a metallic oxide mixed with serum thickens it, whilst itself passes into a metallic state. Besides, all the facts relative to the coagulation of the albuminous matter prove, that the more air this substance contains, the more of it it has absorbed, and the more speedily it coagulates by fire, so much the more solid does it become by this agent.

Alkalis render the serum more fluid by effecting a sort of solution of it. Acids alter it in a different manner, increasing its consistency, and coagulating it. This mixture, filtrated, and evaporated after filtration, affords a neutral salt formed of soda and the acid employed : And this fact proves soda to exist in the serum in a naked state, in full possession of all its properties. The coagulum formed in this liquor by the addition of an acid, is very speedily dissolved in ammoniac, which is the genuine solvent of the albuminous part of the blood ; but it does not dissolve at all in pure water. Acids precipitate this matter in union with ammoniac. The coagulum, distilled by naked fire, affords the same products as
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the serum desiccated ; and its carbonaceous residue contains a good deal of carbonate of soda ;—a circumstance which, in Bucquet's opinion, shews, that there exists a portion of this salt in a state of intimate combination, in the serum, which the acid employed to coagulate it does not saturate.

The serum, inspissated, affords azotic gas by the action of the nitric acid, with the help of a moderate heat. On increasing the fire, there is a quantity of nitrous gas disengaged from the mixture : the residue affords oxalic acid, and even a small quantity of malic acid.

The formation and disengagement of the Prussic acid by serum and the nitric acid, is a discovery which furnishes a simpler and more economical process than that of Scheele's, for obtaining this acid pure.

The serum does not decompose calcareous or aluminous neutral salts ; but it acts with sufficient energy in decomposing metallic salts. It is liable to be coagulated by alcohol : this coagulum differs considerably from that formed in the serum by acids, chiefly in its solubility in water, as Bucquet has discovered. This liquid appears, therefore, from these researches, to be an animal mucilage, consisting of water, acidifiable oily bases, muriate and carbonate of soda, with calcareous phosphate : The rose-coloured precipitate which I have obtained by pouring a portion of a nitric solution of mercury into the serum, appears to be owing to the latter of these principles. Although the liquid has scarce any colour, yet nitric acid, and still more nitrate of mercury, produces, when poured into it, a rose or light flesh-colour, which I have had occasion to observe in many other animal liquors. The most singular property

perty of this mucilage,—a property highly worthy of engaging the attention of physicians,—is, its being liable to become concrete by the action of fire and acids. Scheele thought this phenomenon owing to the combination of heat. Its true cause has been taken notice of above.

The clot of the blood affords, by exposure to the heat of a water-bath, an insipid water ; it becomes, at the same time, dry and brittle. It affords, in the retort, an alkaline phlegm, a thick oil, of a foetid, empyreumatic smell, and a good deal of ammoniacal carbonate. The residue which it leaves, is a spongy coal, of a sparkling metallic aspect, difficult to incinerate, and affording, when treated with sulphuric acid, sulphate of soda and sulphate of iron : there remains, after these operations, a mixture of calcareous phosphate with carbonaceous matter. Exposed to an hot atmosphere, the clot putrefies readily enough. When washed with water, this fluid separates it into two very distinct matters ; the one it dissolves, deriving from it a red colour. The solution, treated with different menstrua, exhibits all the same characteristics with the serum, but is found to contain much more iron. The metal is separated by incineration, and by washing the incinerated coal, in order to carry off the saline matters. The remaining part of the lixivium, after the saline matters are carried off, is in the state of oxide of iron, of a brown colour, of considerable beauty. It is usually subject to the attraction of the magnet. Blood is thought to owe its colour to this metal. A very considerable proportion of iron has been extracted from this fluid by Messrs Menghini, Rouelle, and Bucquet.

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The clot, after being washed and cleared from all the red serum which it contains, is in the state of a fibrous white matter; which it remains for us to examine.

The fibrous part of the blood is white and colourless, after being well washed: its taste is insipid. It affords, by distillation on a water-bath, an insipid phlegm, without smell, and liable to putrefaction. Even the gentlest heat hardens this fibrous matter in a singular manner. When exposed suddenly to a strong fire, it shrinks like parchment. By distillation in a retort, it affords an ammoniacal phlegm, a ponderous oil, which is thick and very foetid, and a good deal of ammoniacal carbonate, contaminated with a portion of oil. The residual coal is not very bulky, but compact, ponderous, and easier incinerated than that of the serum. Its ashes are very white: it contains no saline matter, as it must have lost, by the washing, whatever it contained of that kind,—and no iron: it is a sort of residue of an earthy appearance, and seemingly calcareous phosphate.

The fibrous part of the blood putrefies very quickly, and with great facility. When exposed to an hot moist atmosphere, it swells, and affords a good deal of ammoniac. It is not soluble in water: when boiled in that fluid, it becomes hard, and acquires a grey colour. Alkalis do not dissolve it; but even the weakest acids combine with it: The nitric acid disengages from it a considerable quantity of azotic gas, as we are told by M. Berthollet: (I have likewise discovered, that the Prussic acid is formed, which is disengaged in vapour;) and at length dissolves it with effervescence, and the disengagement

disengagement of nitrous gas. When it ceases to emit nitrous gas, the residue is observed to contain oily and saline flakes, swimming in a yellowish liquor: This liquor affords, by evaporation, oxalic acid in crystals; and, at the same time, deposits no inconsiderable quantity of flakes, composed of a peculiar oil, and calcareous phosphate. It appears that hydrogen, carbone, and azote, which constitute the fibrous substance, are separated in different proportions, to combine with the oxygen of the nitric acid, and thus form the Prussic and carbonic acids that are disengaged in gas, and the oxalic and malic acids, that remain in solution, and are separated only by crystallization.

The fibrous matter dissolves also in the muriatic acid, which converts it into a sort of green jelly. The acid of vinegar dissolves it with the help of heat: Water, and especially alkalis, precipitate this fibrous matter from acids. This animal matter is decomposed in these combinations; and when separated, by whatever means, from acids, no longer exhibits the same properties. Neutral salts, and other mineral matters, are incapable of acting upon it. It unites with the albuminous matter, especially with that which is coloured, to form clot. This last substance, as well as the fibrous part, is totally soluble in acids; on account, no doubt, of the combination of this matter with the red serum. From this it appears, that the fibrous part differs greatly from the albuminous matter. It is more of an animal nature than that matter, being a sort of animal gluten, bearing no small resemblance to that of farina, and possessing the remarkable property of becoming concrete by rest and cooling. There is no doubt that this matter, which
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has not been sufficiently attended to by physiologists and pathologists, acts an important part in the animal œconomy. I have a considerable time since observed, that it is deposited in the muscles, and constitutes the fibrous base of those organs, and that substance which is most eminently irritable. I have concluded this substance to merit more attention than it has yet obtained, and have considered it as capable of occasioning, by its excess or deficiency, certain diseases : And I have given my reasons for entertaining such opinions, in a Memoir which is inserted among the Memoirs of the Royal Society of Medicine for the year 1783, &c. It appears that the peculiar acid which the blood affords by distillation, and which M. Chauffier has obtained from it by the action of alcohol, exists in the fibrous part of its substance. For this reason, I have proposed to call it the *crucic acid*, if it should ever be determined to be a peculiar animal acid.

After all these ingenious discoveries concerning the nature of the blood, we are yet far from being sufficiently acquainted with all its chemical properties. We are yet ignorant of the minute difference which subsists between the serum and the fibrous part. The blood has not yet been examined in all its various states ; particularly in different diseases, in which that fluid suffers considerable alterations, such as violent inflammations, the chlorosis, scurvy, &c. Physicians distinguish these alterations only by external appearances ; and it is much to be wished that accurate analyses should determine their nature, in such a manner as to afford a better direction to the practitioner in the art of healing.

I have found the blood of a human foetus to differ in
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three remarkable particulars from that of an adult. It contained no fibrous substance, strictly speaking, but a sort of gelatinous matter : it did not take a bright colour from the contact of air ; nor did it afford any marks of phosphoric acid.

Rouelle has examined the blood of various quadrupeds, the ox, the horse, the calf, the sheep, the hog, the ass, and the goat. He obtained from them the same products which the human blood affords, but in different proportions.

C H A P.

C H A P. III.

Of the Milk.

THE milk is a recrementitial humour, designed by Nature for the nourishment of the young of animals in the first period of their existence. It is of a dead white colour, a mild saccharine taste, and a smell faintly aromatic. The female of the human species, female quadrupeds, and cetaceous animals of the same species, are the only animals that afford milk. No other animal is furnished with organs for the secretion of this humour. It was long thought, that the milk was immediately separated, by glands in the breast, from the blood conveyed into them by the numerous arteries which meet there. But the principles of which milk is known to consist, have not been hitherto proved to exist in the blood : and late discoveries in anatomy have shewn, that the breasts are furnished with a great many lymphatic and absorbent vessels, disposed in a fatty tissue ; and
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the liquor which these contain is perhaps one of the chief constituent principles of milk.

Milk is very different in different animals. In woman it is highly saccharine. Cows milk is mild, and its principles are intimately united. The milk of the goat and the ass possesses peculiar virtues, and is often gently astringent. The properties of milk are liable to vary, as they commonly depend on the nature of the food with which animals are nourished.

Cows milk, which we may take as an instance, as it is so easily procured, is a compound of three different substances ; serum or whey, which is fluid and transparent ; butter and cheese, which have more consistency. These three parts are so mixed and suspended, as to form a sort of animal emulsion.

Milk, distilled by the heat of a water-bath, affords an insipid inodorous phlegm, susceptible of putrefaction. Exposed to a heat somewhat stronger, it coagulates like blood, as has been observed by Bucquet. When stirred and evaporated slowly, it forms a sort of saccharine extract, known by the name of *franchipane*. This extract, dissolved in water, forms Hoffman's whey. Distilled by naked fire, it affords acid, fluid oil, concrete oil, and ammoniacal carbonate. Its residual coal contains a little potash, muriate of potash, and calcareous phosphate.

Milk, exposed to an hot temperature, is liable to pass into a state of spirituous fermentation, in which it forms a sort of wine ; but a considerable quantity of it must be together, in order that this alteration may take place. The Tartars prepare a spirituous liquor from mare's milk. The milk becomes quickly acid, and then

coagulates. The cheese gathers into a mass, leaving the whey separate.

When heated pretty strongly, milk experiences a singular thickening: it swells, forms a pellicle at its surface, which is renewed as fast as it is removed, until the whole of the caseous substance be separated. Messrs Parmentier and Deyeux have ascertained it to be the caseous part which forms these pellicles.

Acids have instantaneously the same effect on milk. They coagulate it; this *coagulum* is again dissolved by alkalis, especially by ammoniac. Boerhaave asserts, that milk boiled with oil of tartar becomes first yellow, and takes afterwards a blood-red colour. He is even of opinion, that it is by some such combination milk is converted in the human body into the state of real blood. Neutral salts, sugar, and gum, likewise coagulate milk, with the help of heat, as has been observed by Scheele.

To make whey, milk must be warmed with an addition of rennet, in the proportion of twelve or fifteen grains to the pint. This substance, being a mixture of milk soured in the stomachs of calves, with the gastric juice, is a fermenting substance which coagulates the caseous part. After this coagulation is effected, the whey is strained from the curds. The flowers of thistles, and artichokes, act on milk in the same way as rennet.

As to gallium, though it has got the name of milk-curdler, it does not possess that property, according to the observations of Messrs Deyeux and Parmentier. The external membrane of the stomachs of calves and birds, when dried and reduced to powder, produces the same effect on milk: a fact which proves,

that the coagulation of this liquor is owing to the dried gastric juice contained in the pores of that membrane.

The serum or whey, prepared in this way, is turbid; it may be clarified with white of eggs and tartar. When the serum or whey is wanted very pure, in order to be examined, no acidulous tartarite of potash should be intermixed with it.

Whey has a mild taste. When prepared from new milk, it contains a saccharine essential salt; but it soon acquires a sour taste, in consequence of that fermentation which takes place in it. This emotion is produced by the alteration of a mucilaginous principle contained in milk; and it is the extrication of this acid from a latent state which separates the whey from the other principles of which milk consists. It will therefore be proper to examine the nature of the acid which is formed in sour milk, and constitutes fermented whey.

It is well known, that milk left to itself, at a temperature of seventy or eighty degrees, suffers, in the space of a few days, a fermentation, which develops an acid, and separates the butter and cheese. The acid which is formed by this fermentation, and acquires, in the space of twelve or fifteen days, all the strength of which it is capable, has been examined by Scheele: We call it the *lactic acid*. The following is the process by which Scheele obtained this acid pure, after attempting ineffectually to separate it from sour milk by distillation. This operation having afforded him only a very small portion of acid, he evaporated sour whey to an eighth part, after filtering it, to separate all the caseous mat-

ter. The animal earth he precipitated by lime-water. He diluted it with three times its weight of water; and separated the lime by oxalic acid. To ascertain whether any oxalic acid remained in it, he assayed it with lime-water; and then evaporated the liquor to the consistency of honey; and precipitated the sugar of milk, and some other extraneous substances, by mixing with it alcohol, which easily dissolves the lactic acid. Lastly, He distilled this solution; and after the alcohol was thus volatilized, the lactic acid remained pure in the retort. Scheele ascribes to this acid the following properties.

Evaporated even to a very thick consistency, it affords no crystals; it attracts moisture from the atmosphere. By distillation, it affords an empyreumatic acid, resembling the pyro-tartareous acid, a little oil, and a mixture of carbonic acid gas, with carbonated hydrogenous gas.

In union with the three alkalis, with barytes, or with lime, the lactic acid forms deliquescent salts. In combination with magnesia, it forms crystals; but these, too, attract moisture from the atmosphere. Most of these salts of milk, or alkaline and earthy lactates, are soluble in alcohol. The acid of milk does not act, in any way, on cobalt, bismuth, antimony, mercury, silver, or gold, even though assisted by a boiling heat. It dissolves zinc and iron, producing from them hydrogenous gas: the former of these salts, lactate of zinc, crystallizes; the other, lactate of iron, forms a deliquescent brown mass.

The lactic acid oxidates and dissolves lead and copper. The lactic solution of lead deposits a little sulphate of lead;

lead; from which it appears, that this animal acid contains a small portion of sulphuric acid. Lastly, It decomposes acetite of potash: This last property, with the rest here mentioned as belonging to it, shew the lactic acid to be different in its nature from vinegar. To these particulars, Scheele adds, that real vinegar may be obtained from milk, by mixing six spoonfuls of alcohol with three pints of milk, and leaving the mixture to ferment in a well-stopped vessel: the gas disengaged by the fermentation of the mixture, must be, from time to time, suffered to escape: at the end of a month, the milk is found changed into good vinegar: it may be then strained through a cloth, and put up in bottles. The celebrated Swedish chemist adds farther, that milk in a bottle, the neck of which enters a vessel filled with the same liquor, undergoes, if exposed in this condition to a heat somewhat superior to the ordinary heat of summer, a fermentation which occasions the disengagement of a large quantity of elastic fluid: This fluid displaces the milk, so as nearly to empty the bottle in the space of two days: The acid produced by this fermentation, which takes place without the contact of air, seems to owe its oxigene, the acidifying base of air, to the decomposition of water.

The whey of sweet milk, separated by rennet, without souring, holds in solution a certain quantity of alkaline substance, known by the name of salt or sugar of milk. Although Kempfer asserts, that the Brachmans have a process for preparing this salt, it appears that Fabricius, Bartholæt or Bartholdi, an Italian physician, first mentioned it to the world, in the year 1619. Etmuller Testi, Werloschnigg, Wallisnieri, Fickius, and Cartheuser,

have successively written concerning it, and described processes for its preparation. Messrs Vulgamoz and Lichtenstein have given very particular accounts of the art of extracting this saline substance, which is prepared in the great way in different places in Switzerland. They there evaporate whey, obtained from milk by skimming and coagulating it with rennet, till it be reduced to the consistency of honey : This substance, put into moulds, and dried before the sun, forms sugar of milk in tablets : these are dissolved in water, clarified with white of eggs, and evaporated to the consistency of a syrup ; and then the liquor is crystallized in the cold : white crystals are formed in it, in rhomboidal parallelepipeds ; the mother-water deposits yellow and brown crystals, which are purified by successive solutions. M. Lichtenstein has examined and analysed the different sugars of milk that are sold in Switzerland at different prices ; and has particularly distinguished, 1. *The sweet sugar of milk*, which is extracted from sweet purified whey : 2. *The acescent sugar of milk*, obtained from sour whey : 3. *Sugar of milk, rendered impure by a mixture of fat particles*, which, according to him, separates in the first crystallization : 4. *Sugar of milk, mixed with oil and common salt*, which is last crystallized : 5. *Sugar of milk, mixed with fat particles, common salt, and sal ammoniac* ; it is glutinous and moist ; treated with fixed alkali, it affords ammoniac : 6. *Lastly, Sugar of milk, mixed with all the above-mentioned substances, and likewise with extractive and caseous matter* ; this last sugar is of the consistency of honey ; it is liable to turn rancid, and is acrid and disagreeable.

Pure

Pure sugar of milk tastes, in a faint degree, like sugar, insipid, and somewhat earthy. By repeated solutions, there is always so much of it lost. It dissolves in three or four parts of hot water: It affords, by distillation, the same products as sugar, according to Messrs Rouelle, Vulgamoze, and Scheele. The first of these chemists obtained, by burning, a pound of this salt, from 24 to 30 grains of ashes; of which three fourths were muriate of potash, and the remaining fourth part carbonate of potash. On a burning coal, sugar of milk melts, swells, gives out a smell of caramel, and burns like sugar. These properties afforded reason for thinking, that this salt would, like sugar, afford oxalic acid, if treated with nitric acid. Scheele's experiments have confirmed this conjecture: But he observes, that a much more considerable proportion of spirit of nitre is necessary for this purpose, than to produce oxalic acid from common sugar; and that 4 ounces of sugar of milk afford 5 drams of oxalic acid: And he has farther discovered, that the residue of sugar of milk that has been treated with nitric acid, when diluted in water, and filtrated, in order to the evaporation and crystallization of the oxalic acid, leaves on the filter a white powder, which he found to possess the characteristics of a peculiar acid, different from the former. This we denominate the *saccho-lactic acid*. The following are its properties, as observed by Scheele:—

This acid is in the form of a white granulated powder. Two drachms of this salt, in a state of considerable purity, on being exposed to heat in a glass-retort, melted, swelled, and turned black. There was sublimated from this matter, a brown salt, the smell of which

was a compound of the smell of benzoin with that of amber, and which weighed 35 grains. This sublimate was acid, soluble in alcohol, but not so easily as in water, and burned on the coals. In the receiver, there was found a brown liquor, which possessed none of the characteristics of an oily substance. In the retort, there remained 11 grains of coaly matter. Both carbonic acid and hydrogenous gas were disengaged during the distillation. The saccho-lactic acid is scarce soluble in water; for an ounce of boiling water dissolves only six grains of it; and even of that quantity, a fourth part is precipitated by cooling.—M. de Morveau says, that this acid effervesces with an hot solution of carbonate of potash. Saccho-lacte of potash, crystallized by cooling, was dissolved in eight times its weight of hot water, and crystallized anew by the cooling of the liquor. Saccho-lacte of soda is susceptible of crystallization, and only five parts of water are requisite to dissolve it. This acid likewise combines with ammoniac; but heat deprives the neutral salt thus formed of its volatile base. With barytes, aluminous earth, magnesia, and lime, the saccho-lactic acid forms salts which are almost insoluble. It acts with little energy on metals; with their oxides it forms neutral salts, which are scarce soluble. It precipitates nitrates of mercury, lead, and silver; as also muriate of lead.

When Scheele first made this discovery, he thought, that the white powder deposited by the oxalic acid, obtained from sugar of milk by the nitric acid, was nothing but calcareous oxalate, the formation of which was owing to lime which might possibly be contained in this animal salt; but he was soon undeceived, when, on
pouring

pouring a small portion of pure oxalic acid into a solution of sugar of milk, he found the mixture to afford no precipitate. Yet M. Hermstadt, who, in Crell's Journal, has given two Memoirs on sugar of milk, in the second of which he enters into a particular examination of this earthy acid; thinks, notwithstanding Scheele's experiments, that it must be a compound of oxalic acid and lime with a fat matter. But M. de Morveau, examining, with his usual accuracy, the experiments of this chemist, and comparing them with those of Scheele, has shewn, in the new *Dictionnaire Encyclopédique*, that M. Hermstadt has not accomplished his object, and that even the results of his experiments rather confirm than contradict the discoveries of the Swedish chemist. M. de Morveau has himself made several ingenious experiments, which concur to establish the same fact.—To these particulars we may add, that the oxalic and the saccho-lactic acids do not exist ready-formed in sugar of milk; and that this salt contains only the bases which attract oxygen, or the acidifying principle from the nitric acid. We may farther observe, that new experiments may one day, perhaps; shew the saccho-lactic acid to be nothing but a modification of some other vegetable acid; for every thing tends to prove, that the principles of whey have belonged originally to the vegetables with which the animals that afford it are nourished.

Baron Haller represents sugar of milk as existing in the following proportions, in the milk of the following animals:

Four ounces of sheep's milk afford from 35 to 37 grains of sugar of milk:

The

The same quantity of goat's milk	-	from 47 to 49
_____ of cow's milk	-	from 53 to 54
_____ of woman's milk		from 58 to 67
_____ of mare's milk	-	from 69 to 70
_____ of afs's milk	-	from 80 to 82

Rouelle has observed, that after the sugar of milk is extracted from the whey of cow's milk, it cools into a sort of jelly; and accordingly believes it to contain gelatinous matter.

The cheese, or caseous part of milk, is formed into a mass, and separated from the other parts of the liquid, by the action of fire, by the acid fermentation to which milk is liable, and by the intermixture of acids. This matter, when well washed, is white and solid, like the albumen of the blood, when coagulated by heat. A gentle heat hardens it. By distillation on a water-bath, it affords an insipid phlegm, subject to putrefaction.

Dried cheese affords, by distillation in a retort, an alkaline phlegm, a ponderous oil, and a considerable proportion of ammoniacal carbonate. Its coaly residue is dense, very difficult to incinerate, and incapable of affording fixed alkali. When treated with nitric acid, it is found to contain lime and phosphoric acid.

Cheese putrefies in a hot temperature: It swells, diffuses a noisome smell, becomes half-fluid, and, in consequence of the disengagement of a strong-smelling and highly mephitic gas, which with difficulty escapes from this viscid matter, is covered over with froth.

Cheese is not soluble in cold water; and hot water hardens it. Scheele has observed, that when it has been precipitated

precipitated by an acid, boiling water becomes capable of dissolving a part of it.

The alkalis dissolve it: ammoniac especially, when a few drops of it are poured into milk coagulated by an acid, causes the *coagulum* in a short time to disappear.

Concentrated acids also dissolve cheese. The nitric acid disengages azotic gas from it. The vegetable acids do not dissolve it in any sensible degree. The solution of cheese in the mineral acids is precipitated by alkalis; of which, however, too great a quantity dissolves the precipitate again.

The neutral salts, especially muriate of soda, retard the putrefaction of this substance. Alcohol coagulates it.

From these particulars it appears, that cheese is a substance, like the albumen of the blood.

Butter is in part separated from milk by rest, and collected on the surface. But being, in this state, mixed with a good deal of serum and caseous matter, it is separated from these matters by rapid agitation. This is the art of making or churning butter.

In the separation of the cream, and in the formation of the butter, a phenomenon takes place, which has not hitherto met with that attention from philosophers which it deserves. The contact of air, and the absorption of oxigene, are necessary to the production of butter, and to its being obtained in a solid form. It is not completely formed in the milk. In proportion as it collects on the surface, it absorbs oxigene from the atmosphere, and separates itself from the other principles of the milk in consequence of its solidity, and from its now assuming the nature of a concrete oil. Hence it cannot
be

be disengaged by agitation till after a certain period ; and till such time as it has absorbed the requisite quantity of oxigene, it does not constitute a mass, nor does it take a consistence by the strongest agitation.

The serum which swims over churned butter, still retains a portion of this oily substance ; it is yellow, sour, and fat, and is called *butter-milk*. What is called *cream*, is a mixture of cheese and butter, skimmed off milk. It is much more difficult to digest than pure milk. A considerable agitation will reduce this substance into froth : in this state, it is called *whipped cream*.

Pure butter is soft and concrete, of a golden yellow colour, sometimes higher, sometimes lighter, and of an agreeable sweet taste. By a gentle heat, it melts ; and by cooling, becomes solid. When distilled on a water-bath, it affords an almost insipid phlegm. In the retort, it affords an acid, of a very strong pungent smell ; at first, a fluid oil ; and afterwards, a concrete coloured oil, of the same pungent smell with the acid. When these products are rectified, the oil is rendered as fluid and volatile as essential oils. The residual coal is but very scanty. The acid which butter affords by distillation appears to be of the same nature with that which is extracted from grease ; of which we will hereafter speak, under the name of the *sebatic acid*. It may also be extracted in neutral salts, by the application of lime, potash, or soda.

Butter, in a hot temperature, easily becomes acid and rancid. Its acid is then disengaged from a latent state, and is found to have a disagreeable taste. Water and alcohol, by dissolving the acid, reduce the butter nearly

to its former state. Fixed alkali dissolves butter, and forms a real soap with it.

From this detail of particulars, it appears, that butter is an oily substance, of the same nature with concrete vegetable fixed oils.

Fresh butter is sweet, cooling, and relaxing; but it easily becomes sour, and agrees but with few stomachs. Brown butter, the acid of which is developed, is one of the most unwholesome articles of food, and the most difficult to digest, that can be made use of.

Milk is an aliment both agreeable and useful in a great many cases. It is even one of the most valuable medicines that can be prescribed. In diseases affecting the skin or joints, such as the ring-worm, the gout, &c. it sweetens the acrid humours. It even heals up some ulcers that are not of a very malignant sort. It may be impregnated with the aromatic parts of plants: it is then an excellent medicine for the phthisis pulmonaris. All stomachs are not fit for digesting milk: It is generally troublesome to people who are liable to the heart-burn, from too much acidity in the primary passages: It should be almost always administered with great caution. Milk rendered medicinal, by feeding the animal which affords it on certain substances for that purpose, is often used with success.

The milk of different animals possesses different virtues. Woman's milk is sweet, and highly saccharine, and produces very happy effects in the case of a marasmus. Ass's milk is successfully used for the phthisis pulmonaris, and the gout; it commonly relaxes. Mare's milk is nearly of the same quality with that of the ass. Goat's milk is ferous and gently astringent. Cow's milk is thicker

thicker, richer, more nourishing : it is likewise more difficult to digest ; and it is frequently necessary to dilute it with water, or some aromatic infusion, especially if it be found difficult to digest, or if it occasion looseness or vomiting.

Milk is likewise employed externally as emollient and relaxing. It relieves pains, it ripens abscesses, and accelerates their suppuration. It is applied warm, inclosed in a bladder, to the parts affected.



THE END OF VOLUME THIRD.

